PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04B 7/26, H04L 1/12, H04Q 7/38	A1	(11) International Publication Number: WO 95/07578 (43) International Publication Date: 16 March 1995 (16.03.95)

(21) International Application Number: PCT/US94/10087

(22) International Filing Date: 8 September 1994 (08.09.94)

(30) Priority Data:
118,473 8 September 1993 (08.09.93) US

(71) Applicant: QUALCOMM INCORPORATED [US/US]; 6455 Lusk Boulevard, San Diego, Ca 92121 (US).

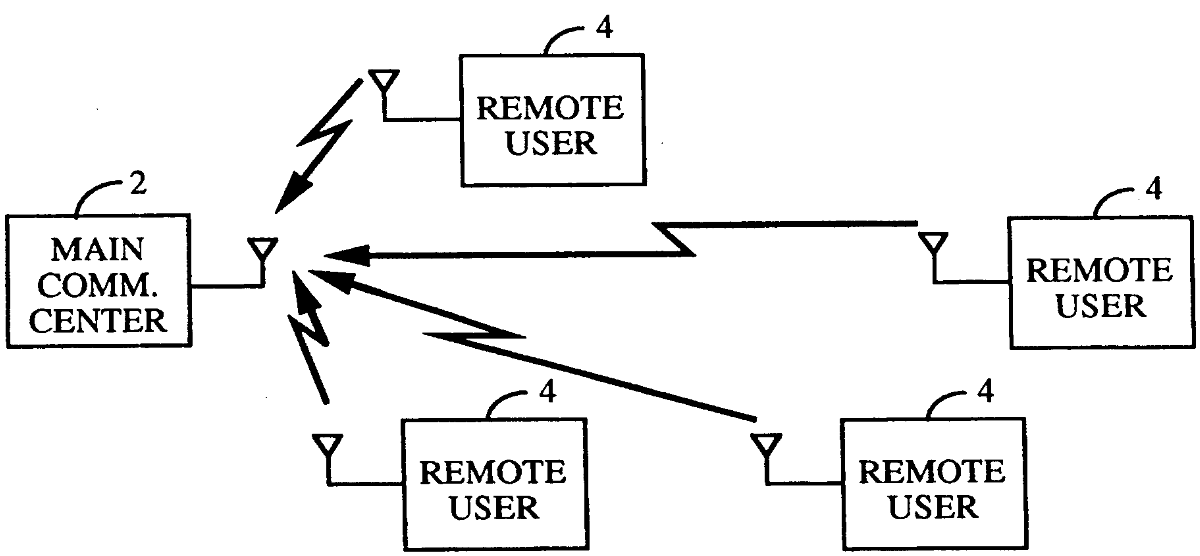
(72) Inventors: GARDNER, William, R.; 1072 Hayes Avenue, San Diego, CA 92103 (US). JACOBS, Paul, E.; 1684 Torrance Street, San Diego, CA 92103 (US). PADOVANI, Roberto; 12634 Futura Street, San Diego, CA 92130 (US). ZIV, Noam, A.; 10968 Corte Playa Barcelona, San Diego, CA 92124 (US). LAM, S., Katherine; 9858 Caminito Calor, San Diego, CA 92131 (US). DeJACO, Andrew, P.; 10424 Flanders Cove, San Diego, CA 92126 (US).

(74) Agent: MILLER, Russell, B.; Qualcomm Incorporated, 6455 Lusk Boulevard, San Diego, CA 92121 (US).

(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD).

Published
With international search report.

(54) Title: METHOD AND APPARATUS FOR DETERMINING THE TRANSMISSION DATA RATE IN A MULTI-USER COMMUNICATION SYSTEM



(57) Abstract

A method and apparatus for controlling the data rates for communications to and from a base station (2) and a plurality of remote users (4). The usage of the communications resource whether the forward link resource, from base station (2) to remote users (4), or reverse link resource, from remote users (4) to base station (2), is measured. The measured usage value is compared against at least one predetermined threshold value and the data rates of communications or a subset of communications on said communications resource is modified in accordance with said comparisons.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	**GB**	United Kingdom	**MR**	Mauritania
AU	Australia	**GE**	Georgia	**MW**	Malawi
BB	Barbados	**GN**	Guinea	**NE**	Niger
BE	Belgium	**GR**	Greece	**NL**	Netherlands
BF	Burkina Faso	**HU**	Hungary	**NO**	Norway
BG	Bulgaria	**IE**	Ireland	**NZ**	New Zealand
BJ	Benin	**IT**	Italy	**PL**	Poland
BR	Brazil	**JP**	Japan	**PT**	Portugal
BY	Belarus	**KE**	Kenya	**RO**	Romania
CA	Canada	**KG**	Kyrgystan	**RU**	Russian Federation
CF	Central African Republic	**KP**	Democratic People's Republic of Korea	**SD**	Sudan
CG	Congo			**SE**	Sweden
CH	Switzerland	**KR**	Republic of Korea	**SI**	Slovenia
CI	Côte d'Ivoire	**KZ**	Kazakhstan	**SK**	Slovakia
CM	Cameroon	**LI**	Liechtenstein	**SN**	Senegal
CN	China	**LK**	Sri Lanka	**TD**	Chad
CS	Czechoslovakia	**LU**	Luxembourg	**TG**	Togo
CZ	Czech Republic	**LV**	Latvia	**TJ**	Tajikistan
DE	Germany	**MC**	Monaco	**TT**	Trinidad and Tobago
DK	Denmark	**MD**	Republic of Moldova	**UA**	Ukraine
ES	Spain	**MG**	Madagascar	**US**	United States of America
FI	Finland	**ML**	Mali	**UZ**	Uzbekistan
FR	France	**MN**	Mongolia	**VN**	Viet Nam
GA	Gabon				

METHOD AND APPARATUS FOR DETERMINING THE TRANSMISSION DATA RATE IN A MULTI-USER COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communications systems. More particularly, the present invention relates to a novel and improved method and apparatus for maximizing total average service quality to users in a multi-user communication system by controlling the data transmission rates to and from users of the multi-user communication system.

II. Description of the Related Art

The term "multiple access" refers to the sharing of a fixed communications resource by a plurality of users. A typical example of such a fixed communications resource is bandwidth. There are three basic ways to increase the throughput or data rate of an individual user accessing a communications resource. The first way is to increase the transmitters radiated power or alternatively to reduce system losses so that the received signal to noise ratio (SNR) is increased. The second way is to increase the allocation of bandwidth to the user. The third approach is to make allocation of the communications resource more efficient.

Some of the more common methods of providing multiple access to a communications resource involve both analog and digital communication modulation schemes. Such schemes include frequency division, time division and spread spectrum techniques. In frequency division multiple access (FDMA) techniques, each user is allocated one or more specific sub-bands of frequency. In time division multiple access (TDMA) techniques, periodically recurring time slots are identified, and for each segment of time each user is allocated one or more time slots. In some TDMA systems, users are provided a fixed assignment in time, and in other systems users may access the resource at random times. In spread spectrum communications, users share a common frequency band. Using frequency hopping (FH) modulation, the signal is modulated upon a carrier which changes in frequency according to a predetermined plan. In direct sequence (DS) modulation, the user signal is modulated with a pseudorandom code. In one type of code division multiple access (CDMA) technique which uses

direct sequence spread spectrum modulation, a set of orthogonal or nearly orthogonal spread spectrum codes (each using full channel bandwidth) are identified, and each user is allocated one or more specified codes.

In all multiple access schemes, a plurality of users shares a communications resource without creating unmanageable interference to each other in the detection process. The allowable limit of such interference is defined to be the maximum amount of interference such that the resulting transmission quality is still above a predetermined acceptable level. In digital transmission schemes, the quality is often measured by the bit error rate (BER) or frame error rate (FER). In digital speech communications systems, the overall speech quality is limited by data rate allowed for each user, and by the BER or FER.

Systems have been developed to minimize the data rate required for a speech signal while still providing an acceptable level of speech quality. If speech is transmitted by simply sampling and digitizing the analog speech signal, a data rate on the order of 64 kilobits per second (Kbps) is required to achieve a speech quality equivalent to that of a conventional analog telephone. However, through the use of speech analysis, followed by the appropriate coding, transmission, and resynthesis at the receiver, a significant reduction in the data rate can be achieved with a minimal decrease in quality.

Devices which employ techniques to compress speech by extracting parameters that relate to a model of human speech generation are typically called vocoders. Such devices are composed of an encoder, which analyzes the incoming speech to extract the relevant parameters, and a decoder, which resynthesizes the speech using the parameters which are received from the encoder over the transmission channel. As the speech changes, new model parameters are determined and transmitted over the communications channel. The speech is typically segmented into blocks of time, or analysis frames, during which the parameters are calculated. The parameters are then updated for each new frame.

A more preferred technique to accomplish data compression, so as to result in a reduction of information that needs to be sent, is to perform variable rate vocoding. An example of variable rate vocoding is detailed in U.S. Patent Application Serial No. 08/004,484 entitled "Variable Rate Vocoder," assigned to the assignee of the present invention and incorporated herein by reference. Since speech inherently contains periods of silence, i.e. pauses, the amount of data required to represent these periods can be reduced. Variable rate vocoding most effectively exploits this fact by

reducing the data rate for these periods of silence. A reduction in the data rate, as opposed to a complete halt in data transmission, for periods of silence overcomes the problems associated with voice activity gating while facilitating a reduction in transmitted information, thus reducing the overall interference in a multiple access communication system.

It is the objective of the present invention to modify the variability of the transmission rate of variable rate vocoders, and any other variable rate data source, in order to maximize utilization of the communications resource.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and apparatus for maximizing total average service quality to users in a multi-user communication system by controlling the data transmission rates to and from users of the multi-user communication system.

In the present invention, usage of the available communication resource is monitored. When the usage of the available communication resource becomes too great for a given communications link, and thus the quality falls below a predetermined limit, the data rate to or from the users is limited to free up a portion of the available communication resource. When the usage of the communications resource becomes small, the data rate to or from the users is allowed to increase above the previous limit.

For example, if the communications link from remote users to a main communications center, hereafter known as the reverse link, becomes overloaded, the main communications center transmits a signaling message requesting that the users, or selected ones of the users, decrease their average transmission data rate. At the remote user end, the signaling message is received and the transmission rate for the remote user is lowered in accordance with the signaling message.

The remote user, in the example, may be transmitting speech data or other digital data. If the user is transmitting speech data, then his transmission data rate may be adjusted using a variable rate vocoder as is described in above mentioned Application Serial No. 08/004,484. The present invention is equally applicable to any variable rate vocoding strategy when the remote user is transmitting speech data. If the user is transmitting digital data that is not speech data, the system can optionally instruct the remote user to modify the transmitted data rate for the specific digital data source.

On the communication link between the main communication center and the remote users, hereafter known as the forward link, the main communication center monitors the fraction of its total resource capacity that is being used for communicating to the remote users. If the fraction of the communications resource being used is too large, the main communication center will decrease the permitted average transmission data rate to each user or a subset of users. If the fraction of the communications resource being used is too small, the main communication center will permit the average data rate for each user to increase. As in the reverse link, the control of the data rate may be selective in nature based upon the nature of the data (speech or non-speech) being transmitted to the remote users.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters are identified correspondingly throughout and wherein:

Figure 1 is a block diagram illustrating multiple remote (mobile) users accessing a main communications center (cell base station);

Figure 2 is a block diagram illustrating the effects of a multi-cell (multiple main communications centers) environment on data reception at a remote (mobile) user;

Figure 3 is a graph of average service quality versus number of users at a particular average transmission data rate;

Figure 4 is a graph of average service quality versus number of users for three different average transmission data rates;

Figure 5 is a flowchart of the system monitor and control operation;

Figure 6 is a communication resource pie chart for forward link communications;

Figure 7 is a communication resource pie chart for reverse link communications;

Figure 8 is a communication resource pie chart illustrating the actions to be taken with respect to different fractions of resource usage;

Figure 9 is a communication resource pie chart illustrating conditions under which the data rate would be decreased by the control mechanism of the present invention

Figure 10 is a communication resource pie chart illustrating the effects of decreasing the data rate of the previous communications resource;

Figure 11 is a block diagram of the monitor and control system for controlling reverse link communications located at the main communications center;

Figure 12 is a block diagram of the monitor and control system for controlling reverse link communications located at the remote user; and

Figure 13 is a block diagram of the forward link monitor and control apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates the multi-user communications system communications between remotes users 4 and the main transmission center 2. In the exemplary embodiment these communications are conducted by means of a code division multiple access (CDMA) multi- user scheme, which is detailed in U.S. Patent Serial No. 4,901,307 entitled "Spread Spectrum Multiple Access Communication System Using Satellite of Terrestrial Repeaters (CDMA)," and U.S. Patent Serial No. 5,103,459 entitled "System and Method for Generating Signal Waveform in a CDMA Cellular Telephone System (CDMA)," both assigned to the assignee of the present invention and incorporated by reference herein. The communications that occur from the remote users to the main transmission center are referred to as reverse link communications. The communications link that enables communications from remote users 4 to a cell base station 2 is referred to as the reverse link. In a CDMA system, system user capacity is a function of the level of interference in the system.

Figure 2 illustrates the two main issues that result in the need for the control of the data rate to reduce interference and increase capacity. In the exemplary embodiment of a CDMA multi-cell cellular communications network, the main capacity limit on forward link communications is the interference from neighboring cells as illustrated by the propagation lines drawn from the cell base stations 12 and the single remote user or mobile station 10. The second effect on forward link capacity in the present embodiment is illustrated by the second propagation path 18 from a single cell base station to a mobile station 10. The cause of this effect, known as multipath, is reflection off of obstruction 16 which may take the form of a

building, a mountain, or any other object that is capable of reflecting electromagnetic waves.

In the exemplary embodiment, interference is received by remote user 10 from cell base stations 12 which are not communicating with the remote user, and interference is received by multipath signals from obstruction 16. In the exemplary embodiment, the operation of a group of cells is overseen by the system controller 14 that provides the data to and from a public telephone switching network (not shown). These communications are referred to as forward link communications.

In systems like time division multiple access (TDMA) and frequency division multiple access (FDMA), a "hard" capacity limit exists due to the finite number of time slot or frequency sub-band divisions, respectively. When all of the time slots or subbands are allocated to users, the "hard" capacity limit is reached and service to any additional user is impossible. Though the users that have accessed the system before the capacity limit remain unaffected by any excluded users, the average quality of service to all users drops beyond the capacity limit since the quality of service for each additional user denied service is zero.

In multiple access schemes such as code division multiple access (CDMA) and random access systems like ALOHA and slotted ALOHA systems, a "soft" capacity limit exists. For these types of multiple access systems, the increase of the number of system users beyond a capacity limit causes a decrease in the quality of service to all users of the system. In a CDMA system, the transmissions of each user are seen as interference, or noise, to each other user. Beyond the soft capacity limit of a CDMA system, the noise floor becomes large enough to cause the predetermined allowable BER or FER to be exceeded. In random access schemes, each additional user increases the probability of a message collision. Beyond a capacity limit the message collisions grow so frequent that the need for retransmission or the resultant lost data causes the communication quality of all users to suffer.

Figure 3 is a graph of the average quality of service to users of such a multiple access communication system versus the number of users occupying the system, given a specified average data rate for all users. The average quality (Q_{ave}) of service is defined as:

$$Q_{ave} = \frac{1}{N}\sum_{i=1}^{N} Q_i \qquad (1)$$

where Q_i is quality of service to user i and N is the number of users on the system.

Figure 3 also illustrates a quality line above which the average service quality is acceptable and below which the service quality is unacceptable. The intersection of the quality line with the plot of quality versus number of users curve defines the capacity limit of the system at the data rate of the system. In the exemplary embodiment of a CDMA system, messages are transmitted in 20 ms frames, and a tolerable frame error rate of 1% dictates the position of the quality line in the exemplary embodiment. It is understood that different frame sizes and error rates are equally applicable to the present invention.

Figure 4 illustrates three plots 20, 22, and 24 of average quality of service versus number users for three progressively decreasing average data rates. Plot 20 corresponds to the quality curve for a high average data rate, plot 22 corresponds to the quality curve for a moderate average data rate, and plot 24 corresponds to the quality curve for a low average data rate.

The first important feature in the plots is that the intersection of the plots with the vertical axis is progressively lower for lower link data rates. Below capacity limits, higher allowable data rates correspond to higher quality, since a high data rate allows more precise quantization of the parameters in the variable rate speech coder, resulting in cleaner sounding speech.

The second important feature in the plots is the intersections of the quality line with the three plots. The intersections of the quality line with each of the curves 20, 22 and 24 provides the capacity limit for the system at the respective data rates of curves 20, 22 and 24. The system capacities labeled CAP A, CAP B, and CAP C are the number of users that can access the system at the data rates of each of curves 20, 22 and 24. The capacity limit at a given data rate is obtained by dropping a vertical line, as shown in the diagram, from the intersection of the plot and the quality line to the horizontal axis representing the number of users. The capacity of the system increases for a fixed quality level as the data rate decreases.

Figure 5 is a flowchart illustrating the method of maximizing the average quality by controlling the data rate of transmission on the system. At block 30 the amount of communications resource that is in use is determined, based on the number of users accessing the system on the given link and the data rate transmitted by each user. The usage value computed in block 30 is passed to block 32. In block 32 the usage value is compared against a lower threshold. If the usage value is below the lower threshold

then the operation goes to block 34 where it is determined if the link is operating at a predetermined data rate maximum. If the system is operating at the predetermined data rate maximum, the operation moves to block 38 and no action is taken. If the system is operating below the predetermined data rate maximum, the operation proceeds to block 36 and the link data rate is increased.

If back at block 32 it is determined that the link usage is not too low, the operation proceeds to block 40 where the usage is compared against an upper threshold. If in block 40 the link usage is determined to be below the upper threshold, the operation proceeds to block 41 and no action is taken. If on the other hand, the link usage exceeds the upper threshold in block 40, the operation proceeds to block 42. In block 42, the system data rate is compared against a predetermined minimum. If the system data rate is greater than this predetermined minimum then the operation proceeds to block 44 where the link data rate is decreased.

If at block 42 the link data rate was determined to be equal to the minimum link data rate then the operation proceeds to block 46. At block 46 the system compares the usage to a predetermined usage maximum. If the communications resource is exhausted, that is the usage is equal to the predetermined maximum, then the operation proceeds to block 48 and access by any additional users is blocked. If the usage is below the predetermined usage maximum then, then operation proceeds to block 50 and no action is taken.

In TDMA systems, data rates can be modified by spreading data of a given user among a plurality of allocated time slots or combining the data of a plurality of users with selected ones of allocated time slots. In an alternative implementation variable data rates could be achieved in a TDMA system by allocating time slots of varying length to different users. Similarly, in FDMA systems data rates can be modified by spreading data of a given user among a plurality of allocated frequency sub-bands or combining the data of a plurality of users with selected ones of allocated frequency sub-bands. In an alternative implementation variable data rates in a FDMA system could be achieved by allocating varying frequency sub-bands sizes to different users.

In random access systems the probability of message collisions is proportional to the amount of information each user needs to send. Therefore, the data rate can be adjusted directly by sending varying size packets of data or by sending the packets at varying time intervals between transmission.

In the exemplary embodiment using a CDMA system, the amount of data necessary for transmission of speech is adjusted by use of a variable rate vocoder as detailed in Application Serial No. 08/004,484 mentioned above. The variable rate vocoder of the exemplary embodiment, provides data at full rate, half rate, quarter rate and eighth rate corresponding to 8Kbps, 4Kbps, 2Kbps and 1Kbps, but essentially any maximum average data rate can be attained by combining data rates. For example, a maximum average rate of 7Kbps can be attained by forcing the vocoder to go to half rate every fourth consecutive full rate frame. In the exemplary embodiment, the varying size speech data packet, is segmented and segments are provided at randomized times as is detailed in U.S. Patent Application Serial No. 07/846,312 entitled "Data Burst Randomizer," assigned to the assignee of the present invention and incorporated by reference herein.

A useful way of looking at the issue of communications resource capacity is to view the available communications resource as a pie chart, where the whole pie represents the complete exhaustion of the communication resource. In this representation sectors of the pie chart represent fractions of the resource allocated to users, system overhead, and unused resource.

In a TDMA or FDMA system the whole of the pie chart may represent the number of available time slots or frequency sub-bands in a given allocation strategy. In a random access system, the whole of the pie chart may represent the message rate that is acceptable before message collisions grow so great as to make the transmission link unacceptable. In the exemplary embodiment of a CDMA system, the whole of the pie chart represents the maximum tolerable noise floor wherein the overhead and signal from all other users appear as noise in the reception of the message data to and from the remoter users. In any system configuration, referring back to Figure 3, the whole of the resource pie represents the intersection of the quality line with the average quality versus number of users plot.

Figure 6 illustrates an example of a general forward link capacity pie chart. The first sector of the resource pie labeled OVERHEAD represents the portion of the transmission signal that does not carry message information. The OVERHEAD fraction of the pie represents the transmission of non-message non-user-specific data and in the exemplary embodiment is a fixed fraction of the communication resource though in other systems this overhead may vary with the number of users or other factors. The OVERHEAD may include base station identification information, timing information and base station setup information among other things. The

OVERHEAD may include pilot channel usage of the communications resource. An example of a pilot channel is detailed in U.S. Patent Serial No. 5,103,459, entitled "System and Method for Generating Signal Waveforms in a CDMA Cellular Telephone System (CDMA)," assigned to the assignee of the present invention and incorporated herein by reference. Each of the following sectors numbered 1-20 represents a the message information directed to a particular user, where the users are numbered 1-20. The last sector of the pie, moving in a clockwise direction, is labeled with a B. The sector labeled with a B represents the remaining fraction of available communication resource before unacceptable link degradation occurs.

Figure 7 is a resource pie chart for the reverse link communications. This pie chart represents the information received at the main transmission center or base station from the remote users. The only significant difference between this pie chart and the previous pie chart is in the reverse link there is no fixed OVERHEAD resource. It should also be noted that in the preferred embodiment each user uses the same fraction of communication resource in order to maximize the quality of service to all users. The method and apparatus for maintaining the condition wherein all users use the same fraction of received communication resource is detailed in U.S. Patent No. 5,056,109 entitled "Method and Apparatus for Controlling Transmission Power in a CDMA Cellular Telephone System" assigned to the assignee of the present invention and incorporated by reference herein. In this approach, each remote user transmits at a power level such that it is received at the base station as all other remote users. Preferably, each remote user transmits at a minimum power level necessary to insure a quality communication link with a base station.

Figure 8 is an action pie chart that represents the actions to be followed with respect to the resource pie charts. Labeled on the pie chart of Figure 7 are three points, a point marked INCREASE RATE, a point marked DECREASE RATE and a point marked BLOCK ADDITIONAL USERS. If the fraction of the resource pie for a given link exceeds the point marked DECREASE RATE, the transmission rate on that link should be decreased to improve the quality of service to the users. For example, if the data rate corresponding to plot 20 in figure 4 was being transmitted by all users and the number of users became greater than CAP A, the data rate would be decreased, and the system would then operate on plot 22 in figure 4. If the fraction of the resource pie for a given link falls below the point marked INCREASE RATE, the transmission rate on that link should be increased to

improve the quality of service to the users. For example, if the data rate corresponding to plot 22 in figure 4 was being transmitted by all users and the number of users dropped below CAP A, the data rate would be increased and the system would operate on plot 20 in figure 4. If the pie reaches the point marked BLOCK ADDITIONAL USERS then any additional users should be blocked from accessing the system. Note that the only way the system would reach the BLOCK ADDITIONAL USERS point is by going through the DECREASE RATE point which implies that the rate could not be further decreased.

Figures 9 and 10 illustrate the effects of decreasing the transmission rate on the resource allocation. In Figure 8, the addition of user 20 has caused the resource allocation to surpass the point at which the transmission rate should be decreased. At this point the transmission rate is decreased and the resource pie for the same users looks like Figure 9. Notice the unused portion of the resource pie labeled B is large enough to permit additional users to access the communication resource. Thus, additional users can access the communication system until the system requires the transmission rate to be decreased again. This process will continue until the rate is at a minimum. If this occurs, the system allows the pie to fill entirely and then any new users are prevented from accessing the system.

In contrast as users leave the communication resource then the fraction of the communication resource that is used decreases below the INCREASE RATE point and the system will increase the transmission rate. This can continue until the transmission rate is increased to a maximum rate or until no users are accessing the communication resource.

Figure 11 illustrates a block diagram for the monitor and control of the reverse link communication resource usage at the main communications center, which may include the cell base station and the system controller. The signals from the remote users are received at receive antenna 60. The received signals are provided to receiver 62 which provides the data in analog or digital form to energy computation element 66 and demodulators 64. The computed energy value from energy computation element 66 is provided to rate control logic 68 which compares the received signal energy to a series of thresholds. In response to the comparisons, rate control logic 68 provides a rate control signal to microprocessors 70 when the signal energy is above an upper threshold or is below a lower threshold. In other embodiments, the rate control logic 68 could also be responsive to external factors which may affect the

performance of the communications channel, such as weather conditions, etc.

The received signal from receiver 62 are provided to demodulators 64, where it is demodulated and the data for a specific user is extracted and provided to the corresponding microprocessor 70. In the exemplary embodiment, as detailed in U.S. Patent Application Serial No. 07/433,031 entitled "Method and System for Providing a Soft Handoff in Communication in a CDMA Cellular Telephone System" assigned to the assignee of the present invention and incorporated by reference herein, the received data is provided by microprocessors 70 to selector cards (not shown) in a system controller 14 that selects a best received data from received data from a plurality of main communication centers (cells), each of which contains a receiver 62 and a demodulator 64, and decodes the best received data using a vocoder (not shown). The reconstructed speech is then provided to a public telephone switching network (not shown).

In addition, microprocessors 70 receive data for forward link transmission from the vocoders (not shown) through the data interface. Microprocessors 70 combine the reverse link rate control signal, when present, with the outgoing forward link data to provide composite data packets to modulators 72. In a preferred embodiment, ones of microprocessors 70 would selectively combine the reverse link rate control when present to with outgoing forward link data. In the preferred embodiment, ones microprocessors 70 are responsive to a signal indicative of overriding conditions where upon the reverse rate control signal is not combined with the outgoing forward link data. In alternate embodiment, certain ones of said microprocessors 70 would not be responsive to the reverse link rate control signal. Modulators 72 modulate the data packets and provide the modulated signals to summer 74. Summer 74 sums the modulated data and provides it to transmitter 76 where amplified and provided to transmission antenna 78.

Figure 12 illustrates a block diagram of the remote user apparatus of the present invention for responding to the rate control signal provided in the exemplary embodiment by main transmission center 2 in figure 1. On the receive path, the signal that comprises encoded speech data and/or signaling data is received at antenna 90, which also serves as the transmission antenna by means of duplexer 92. The received signal is passed through duplexer 92 to demodulator 96. The signal is then demodulated and provided to microprocessor 98. Microprocessor 98 then decodes the signal and passes the speech data and any rate control data that

is sent by the base station to the variable rate vocoder 100. Variable rate Vocoder 100 then decodes the encoded packet of speech data provided from microprocessor 98 and provides the decoded speech data to codec 102. Codec 102 converts the digital speech signal into analog form and provides the analog signal to speaker 106 for playback.

On the transmit path of the remote user, a speech signal is provided through microphone 106 to codec 102. Codec 102 provides a digital representation of the speech signal to the variable rate vocoder 100 which encodes the speech signal at a rate determined in the exemplary embodiment in accordance with the speech activity and the received rate signal. This encoded speech data is then provided to microprocessor 98.

In the exemplary embodiment, the rate control signal is a binary signal indicating to the remote user to increase or decrease the maximum data rate. This adjustment of the data rate is done in discrete levels. In the exemplary embodiment, the remote user will increase or decrease its maximum transmission rate by 1000 bps upon receipt rate control signaling from the cell base station. In practice, this reduces the overall average data rate by 400 to 500 bps, since the vocoder is only encoding the speech at the maximum rate 40-50% of the time in a normal two-way conversation. In the exemplary embodiment, the silence between words is always encoded at the lower data rates.

For example, if the remote user is currently operating with a maximum transmission data rate of full rate or rate 1 (8 Kbps), and a signal decrease its maximum data rate is received, the maximum transmission data rate will be decreased to 7/8 (7 Kbps) by forcing every fourth consecutive full rate frame of data to be encoded at half rate (4Kbps). If on the other hand, the remote user is operating under control of the cell base station at a maximum transmission rate of 3/4 (6 Kbps) and the cell base station signals the remote user to increase its maximum data rate, then the remote user will use a rate 7/8 (7 Kbps) as a maximum transmission data rate. In a simplified embodiment the rates could simply be limited to one of the discrete rates provided by variable rate vocoder 100 (i.e.. rates 1, 1/2, 1/4 and 1/8).

Microprocessor 98, also, receives non-speech data that can include signaling data or secondary data such as facsimile, modem, or other digital data that needs communication to the cell base station. If the digital data being transmitted by the remote user is of a form not conducive to variable rate transmission (i.e. some facsimile or modem data) then microprocessor

98 can decide based upon the service option of the remote user whether to vary the transmission rate in response to the rate control signal.

Modulator 108 modulates the data signal and provides the modulated signal to transmitter 110 where it is amplified and provide through duplexer 92 to antenna 90 and transmitted over the air to the base station. It is also envisioned in the present invention that the remote user could monitor the reverse link communication resource and respond in an open loop manner to adjust its transmission rate.

Figure 13 illustrates a block diagram of an exemplary forward link rate control apparatus. Speech data is provided to vocoders 120 where the speech data is encoded at a variable rate. In the present invention the encoding rate for the speech data is determined in accordance with the speech activity and a rate control signal when present. The encoded speech is then provided to microprocessors 122, which also may receive non-speech data from an external source (not shown). This non-speech data can include signaling data or secondary data (facsimile, modem or other digital data for transmission). Microprocessors 122 then provide data packets to modulators 124 where the data packets are modulated and provided to summer 126. Summer 126 sums the modulated signal from modulators 124 and provides the sum signal to transmitter 128 where the signal is mixed with a carrier signal, amplified and provided to antenna 130 for transmission.

The summed modulated signal from summer 126 is also provided to energy computation unit 132. Energy computation unit 132 computes the energy of the signal from summer 126 for a fixed time period and provides this energy estimate to rate control logic 134. Rate control logic 134 compares the energy estimate to a series of thresholds, and provides a rate control signal in accordance with these comparisons. The rate control signal is provided to microprocessors 122. Microprocessors 122 provide the rate control signal to vocoders 120 for control of the maximum data rate of speech data. Optionally, microprocessors 122 can also use the rate control signal to control the data rate of non-speech data sources (not shown). the rate control signal can be provided selectively to ones of microprocessors 122 or alternately selects ones of microprocessors 122 can be responsive to a globally provided rate control signal.

The open loop form of control on the forward link described above can also operate in a closed loop, which can be responsive to signals from the remote stations indicative of capacity limits being reached, such as high frame error rates or other measurable quantities. Rate control logic 134 can

be responsive to external interferences of various kinds which may also affect the performance of the communications channel.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WE CLAIM:

CLAIMS

1. In a communications network wherein a plurality of remote users each having a transmitter communicate message signals to a communications center having a receiver, a subsystem for optimizing communications quality in accordance with system usage and capacity comprising:

monitor means for determining said system usage and conditionally providing a rate control signal in accordance with said usage level; and

a plurality of response means each collocated with a corresponding one of said remote users for receiving said rate control signal and adjusting said data rate of said corresponding one of said remote users in accordance with.

2. The subsystem of Claim 1 wherein said monitor means is collocated with said transmission center, said subsystem further comprising:

communications center transmitter means for transmitting messages to said remote users and for transmitting said rate control signal to said remote users; and

plurality of remote receiver means, each of said plurality of remote receiver collocated with a corresponding one of said remote users for receiving said rate control signal and for providing said rate control signal to a corresponding one of said response means.

3. The subsystem of Claim 1 wherein said monitor means determines said system usage by measuring the energy of said message signals for a predetermined time period.

4. The subsystem of Claim 1 wherein said response means comprises:

processor means for receiving said rate control signal and providing a rate command signals in response to said rate control signal; and

variable rate vocoder means for receiving speech data and said rate command signals and encoding said speech data at a rate in accordance with said command signals.

5. The subsystem of Claim 4 wherein said variable rate vocoder means further encodes said speech data in accordance with the energy of said speech data.

6. The subsystem of Claim 4 wherein said processor means is further for receiving non-speech data for transmission and for providing said non-speech data at a rate in accordance with said rate control signal.

7. A variable rate transceiver comprising:

a receiver for receiving a signal comprising message data and a rate control command;

a variable rate vocoder for receiving speech data and encoding said speech data in accordance with said rate control command; and

a transmitter for transmitting said encoded speech data.

8. The variable rate transceiver of Claim 7 further comprising:

a demodulator disposed between said receiver and said variable rate vocoder for demodulating said received signal; and

a processor disposed between demodulator and said variable rate vocoder for receiving said demodulated signal and separately providing said message data and said rate control command.

9. The variable rate transceiver of Claim 8 wherein said processor is further for receiving non-speech data for transmission.

10. The variable rate transceiver of Claim 7 further comprising a modulator disposed between said variable rate vocoder and said transmitter for modulating said encoded speech data.

11. The variable rate transceiver of Claim 7 further comprising a modulator disposed between said variable rate vocoder and said transmitter for modulating said encoded speech data.

12. At a base station, an apparatus for controlling the user capacity of said base station comprising:

usage determination means for measuring usage of said base station;

rate control means for comparing said measured usage against at least one predetermined value and selectively providing a rate control signal in accordance with said comparisons; and

transmitter means for transmitting said rate control signal.

13. The apparatus of Claim 12 further comprising processor means for receiving message data for transmission to said remote users and said rate control signal and combining said message data with said rate control signal to provide a composite data packet.

14. The apparatus of Claim 13 further comprising a modulator means disposed between said processor means and transmitter for modulating said composite data packet.

15. In a communication system wherein a base station communicates messages on a forward link with a plurality of remote users an apparatus of controlling the data rate of said message communications, comprising:

usage determination means for determining a usage value of said forward link;

rate control logic means for receiving said usage value, comparing said usage value to at least one predetermined threshold value and conditionally providing a rate control signal in accordance with said comparisons; and

at least one variable rate data source for providing data at a rate in accordance with said rate control signal.

16. The apparatus of Claim 15 wherein said at least one variable rate data source comprises at least one variable rate vocoder means for encoding speech data at variable rates.

17. The apparatus of Claim 15 wherein said usage determination means measures the energy of a signal for transmission to said remote users.

18. A method for optimizing usage of a communications resource, comprising the steps of:

measuring said usage of said communications resource;

comparing said measured usage against at least one predetermined threshold; and

adjusting data rates of communications on said communications resource in accordance with said comparisons.

19. The method of Claim 18 wherein said step of comparing said measured usage against at least one predetermined threshold comprises comparing said usage against a predetermined high usage threshold, and wherein said step of adjusting data rates of communications on said communications resource comprises decreasing the data rate of communications when said usage exceeds said high usage threshold.

20. The method of Claim 18 wherein said step of comparing said measured usage against at least one predetermined threshold comprises comparing said usage against a predetermined low usage threshold, and wherein said step of adjusting data rates of communications on said communications resource comprises increasing the data rate of communications when said usage falls below said low usage threshold.

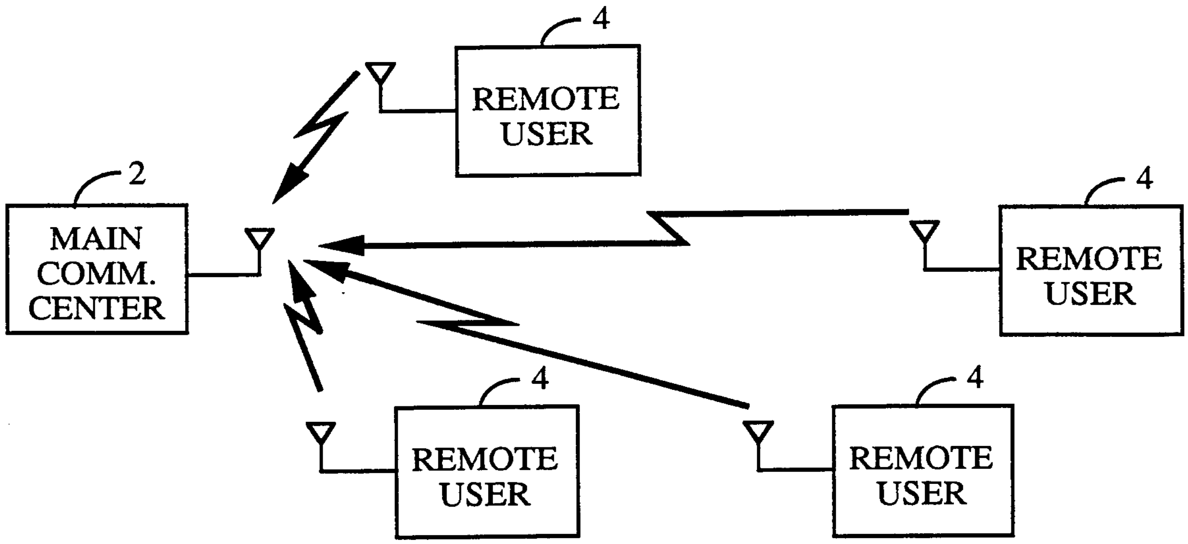

4
REMOTE USER
2
MAIN COMM. CENTER
4
REMOTE USER
4
REMOTE USER
4
REMOTE USER

FIG. 1

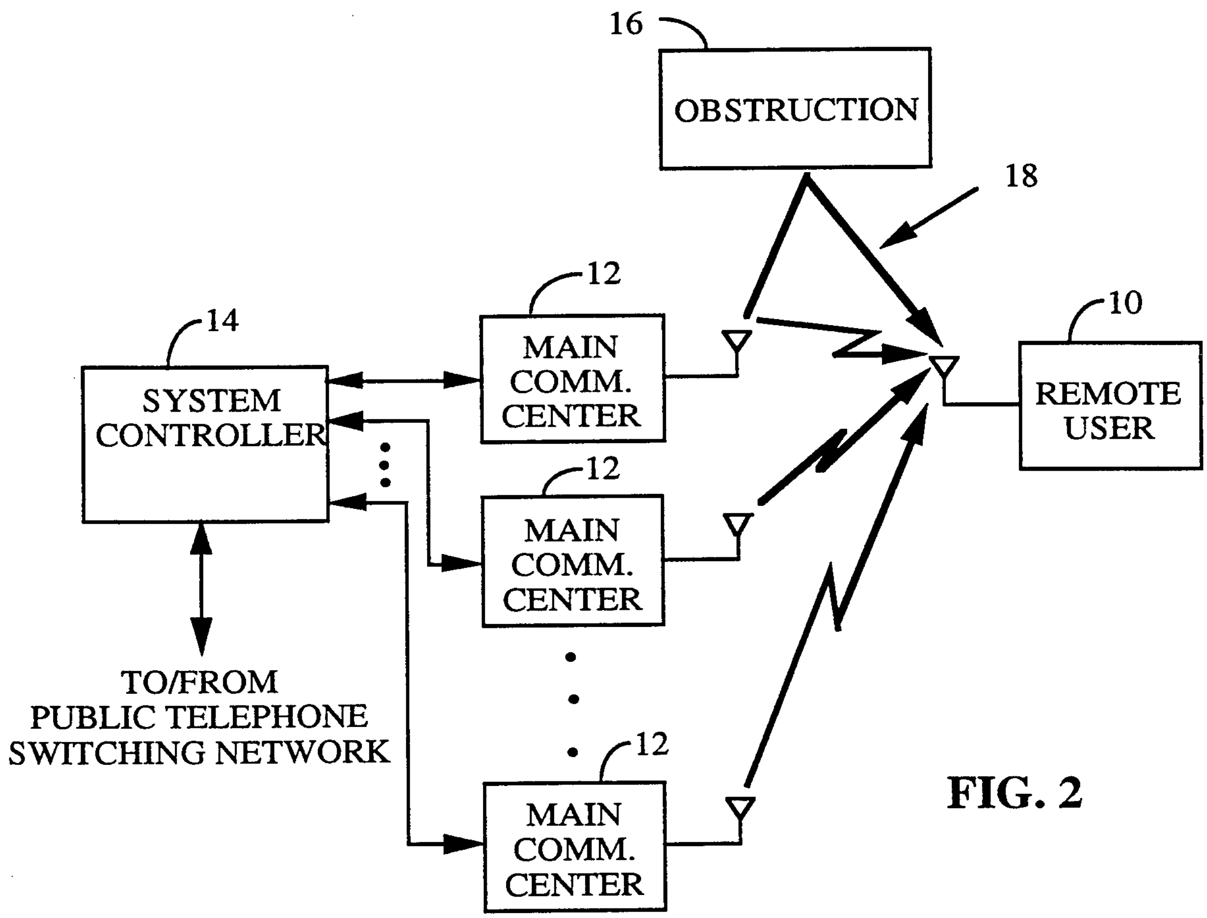
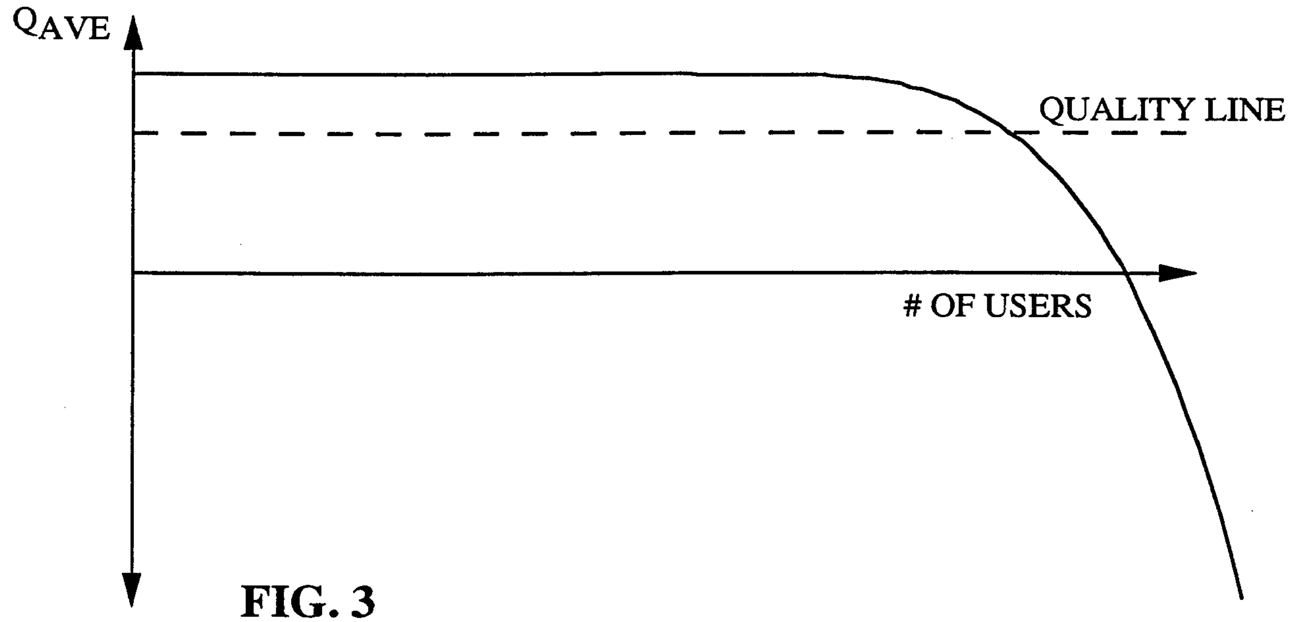
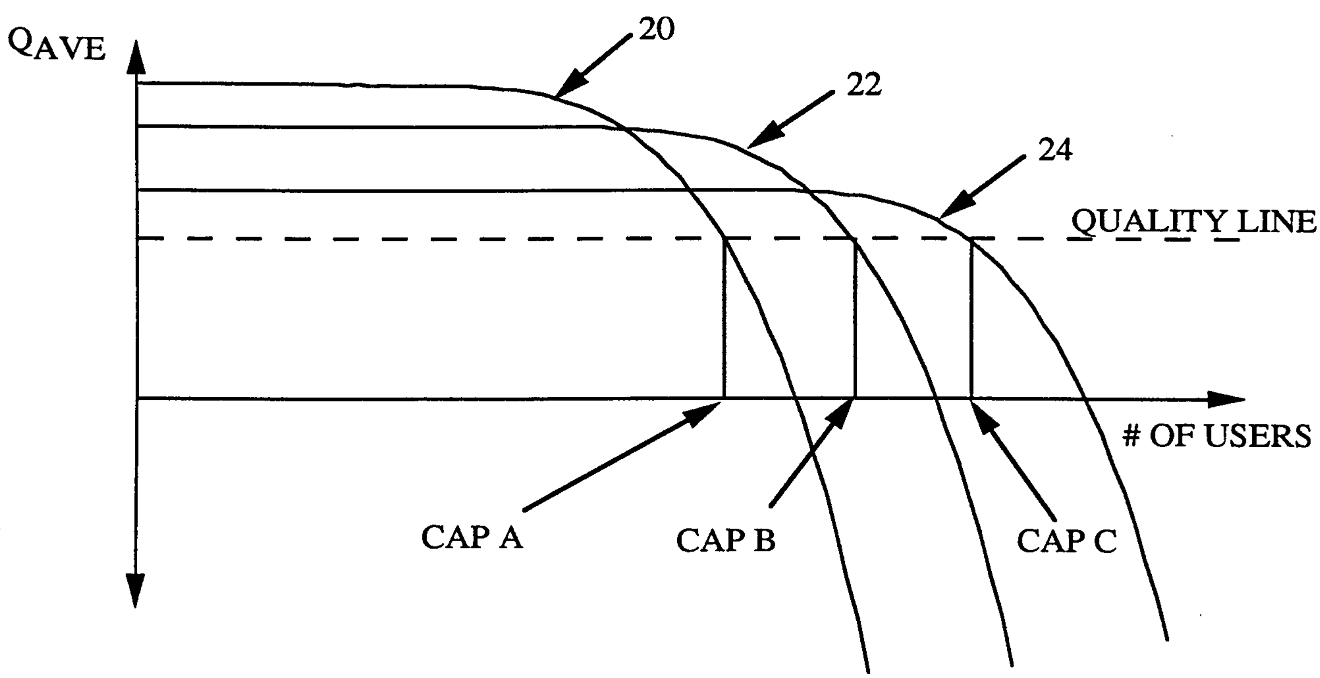

16
OBSTRUCTION
18
14
SYSTEM CONTROLLER
12
MAIN COMM. CENTER
12
MAIN COMM. CENTER
12
MAIN COMM. CENTER
10
REMOTE USER
TO/FROM
PUBLIC TELEPHONE
SWITCHING NETWORK

FIG. 2



Q_{AVE}
QUALITY LINE
OF USERS

FIG. 3



Q_{AVE}
20
22
24
QUALITY LINE
OF USERS
CAP A
CAP B
CAP C

FIG. 4

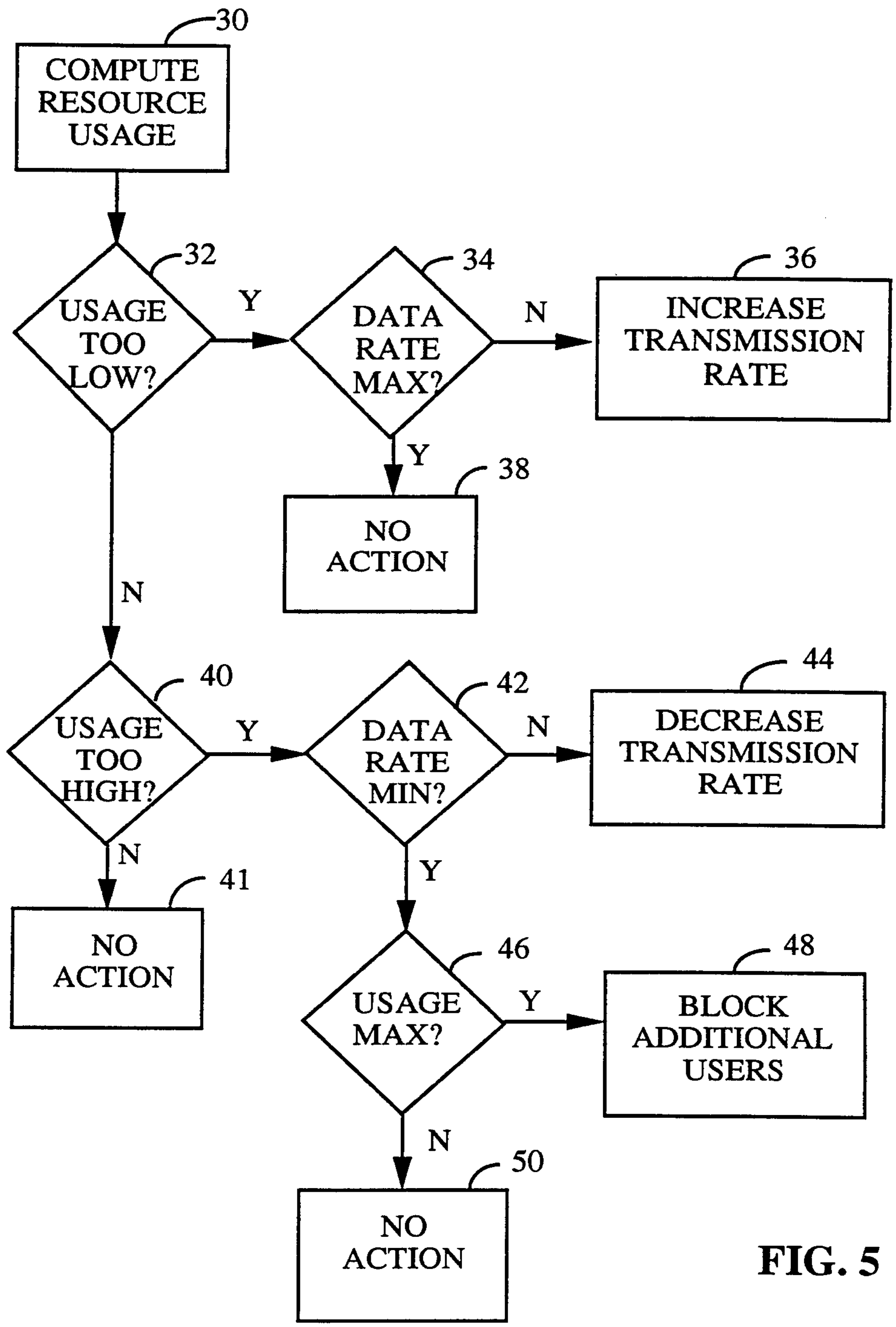

30
COMPUTE RESOURCE USAGE
32
USAGE TOO LOW?
Y
34
DATA RATE MAX?
N
36
INCREASE TRANSMISSION RATE
Y
38
NO ACTION
N
40
USAGE TOO HIGH?
Y
42
DATA RATE MIN?
N
44
DECREASE TRANSMISSION RATE
N
41
NO ACTION
Y
46
USAGE MAX?
Y
48
BLOCK ADDITIONAL USERS
N
50
NO ACTION

FIG. 5

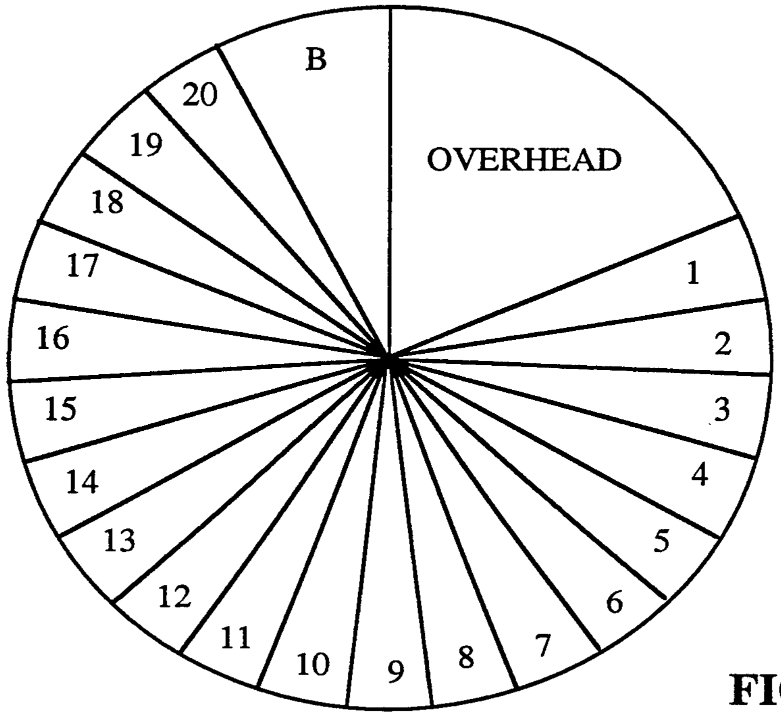

B
OVERHEAD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIG. 6

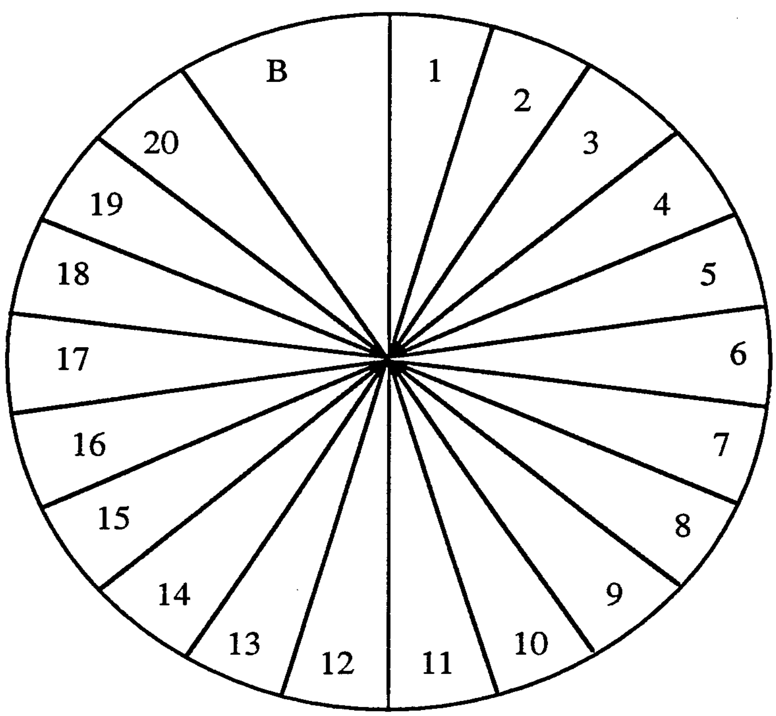

B
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIG. 7

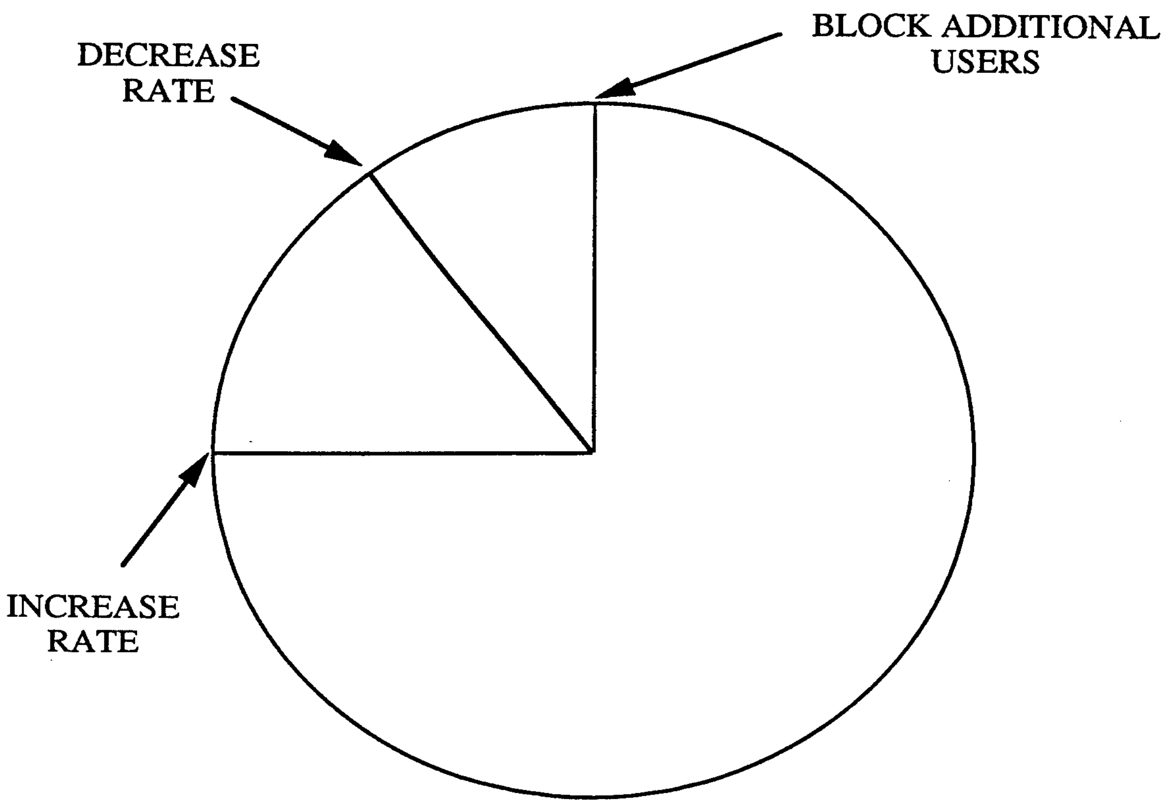


FIG. 8

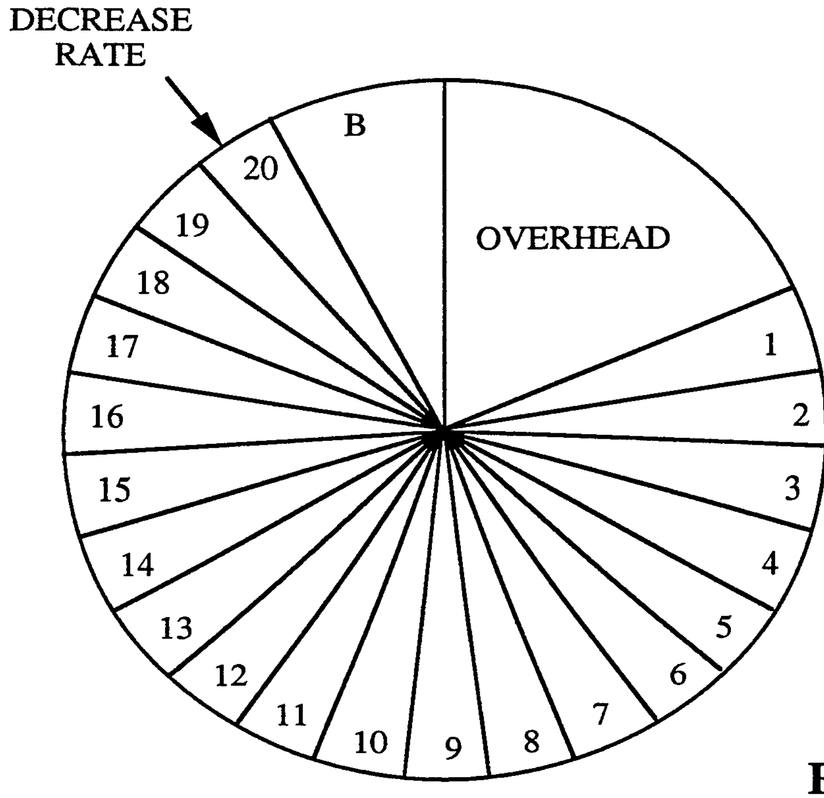

DECREASE RATE
B
OVERHEAD
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

FIG. 9

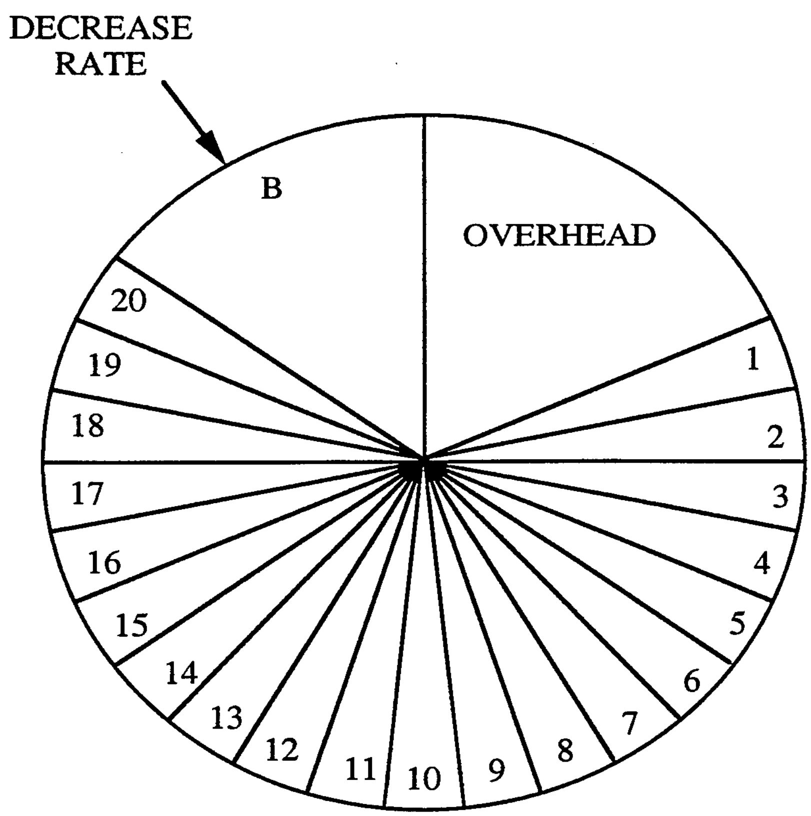

DECREASE RATE
B
OVERHEAD
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

FIG. 10

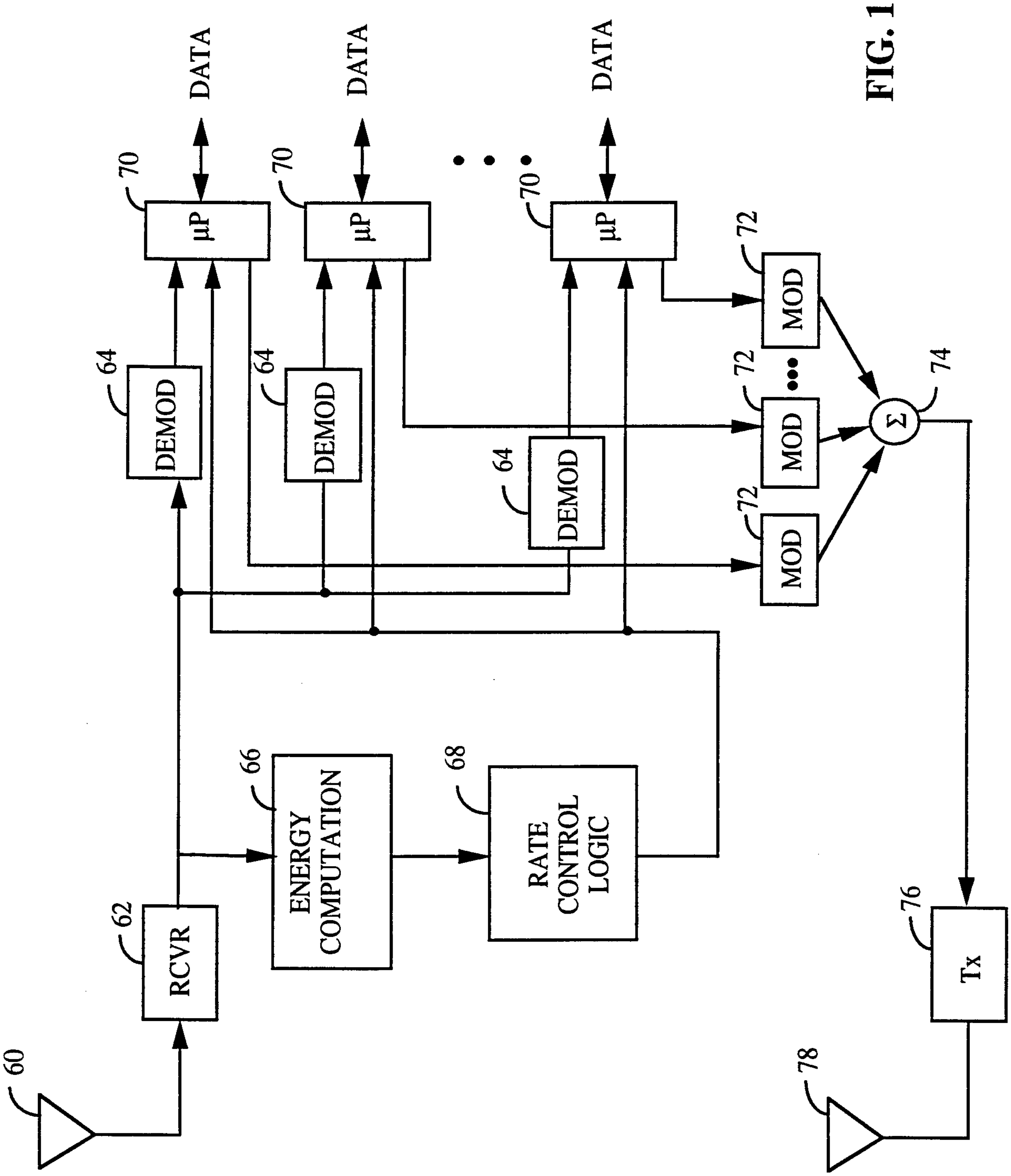

DATA
DATA
DATA
70
70
70
μP
μP
μP
64
64
64
DEMOD
DEMOD
DEMOD
72
72
72
72
MOD
MOD
MOD
MOD
74
Σ
60
62
RCVR
66
ENERGY COMPUTATION
68
RATE CONTROL LOGIC
76
Tx
78

FIG. 11

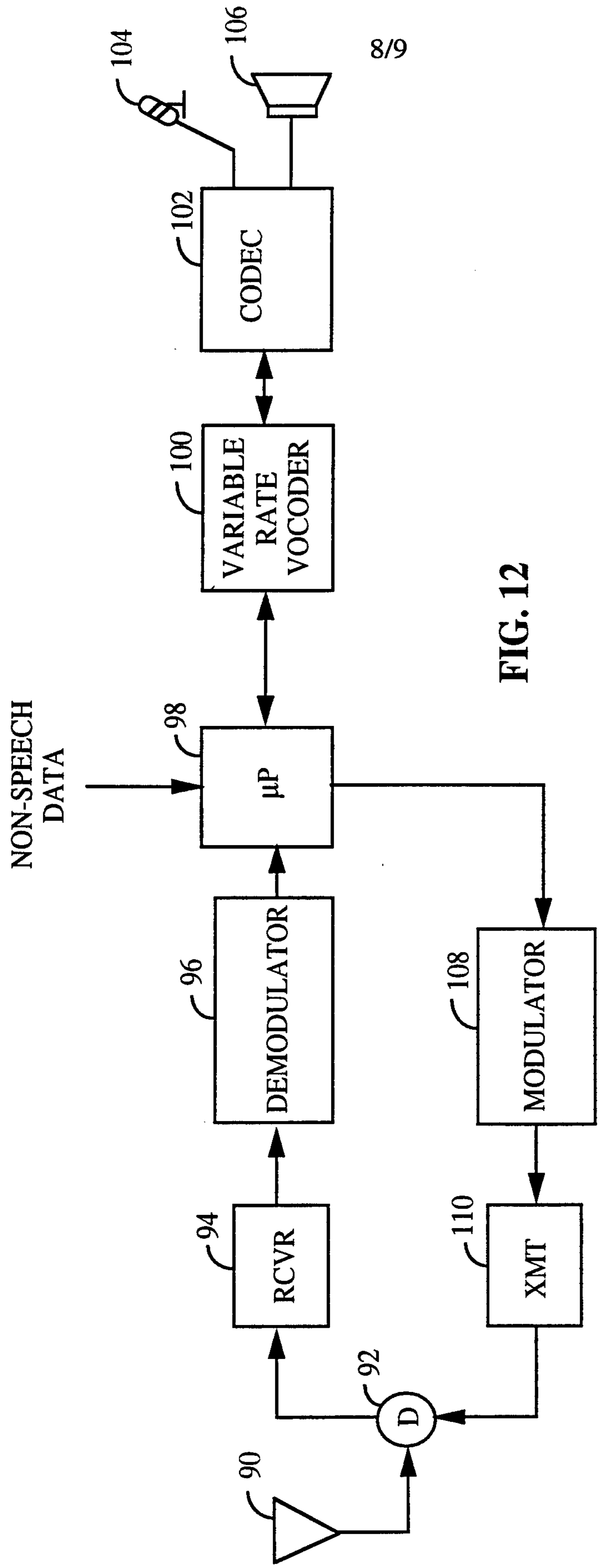

104
106
102
CODEC
100
VARIABLE
RATE
VOCODER
NON-SPEECH
DATA
98
μP
96
DEMODULATOR
108
MODULATOR
94
RCVR
110
XMT
92
D
90

FIG. 12

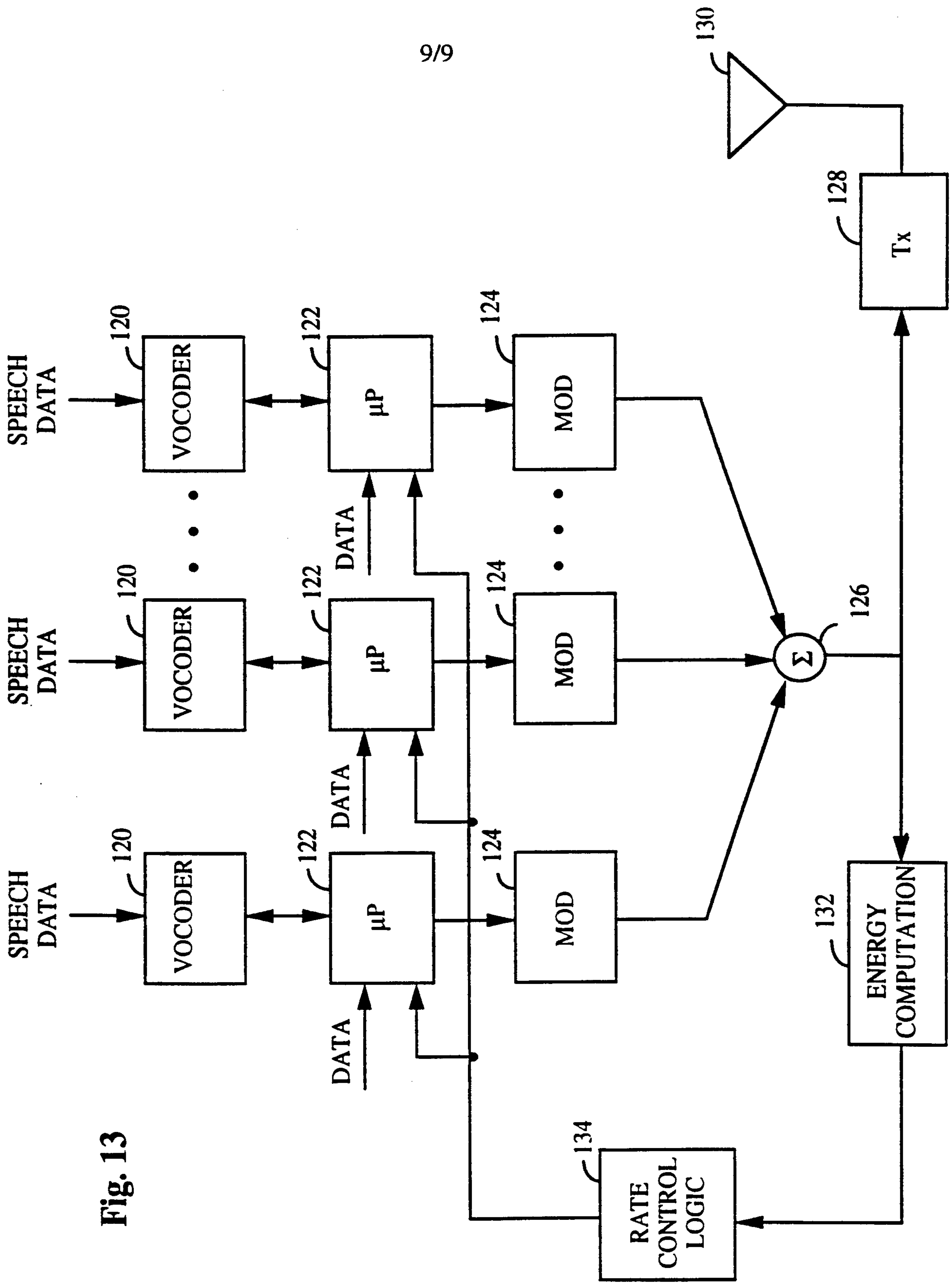

SPEECH DATA
VOCODER
120
µP
122
MOD
124
DATA
Σ
126
Tx
128
130
ENERGY COMPUTATION
132
RATE CONTROL LOGIC
134

Fig. 13

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04Q 7/38

A1

(11) International Publication Number: WO 95/12297

(43) International Publication Date: 4 May 1995 (04.05.95)

(21) International Application Number: PCT/US94/12459

(22) International Filing Date: 28 October 1994 (28.10.94)

(30) Priority Data:

144,901	28 October 1993 (28.10.93)	US
316,155	30 September 1994 (30.09.94)	US

(71) Applicant: QUALCOMM INCORPORATED [US/US]; 6455 Lusk Boulevard, San Diego, CA 92121 (US).

(72) Inventors: GILHOUSEN, Klein, S.; 6474 Jackson Creek Road, Bozeman, MT 59715 (US). PADOVANI, Roberto; 12634 Futura Street, San Diego, CA 92130 (US).

(74) Agents: OGROD, Gregory, D. et al.; Qualcomm Incorporated, 6455 Lusk Boulevard, San Diego, CA 92121 (US).

(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).

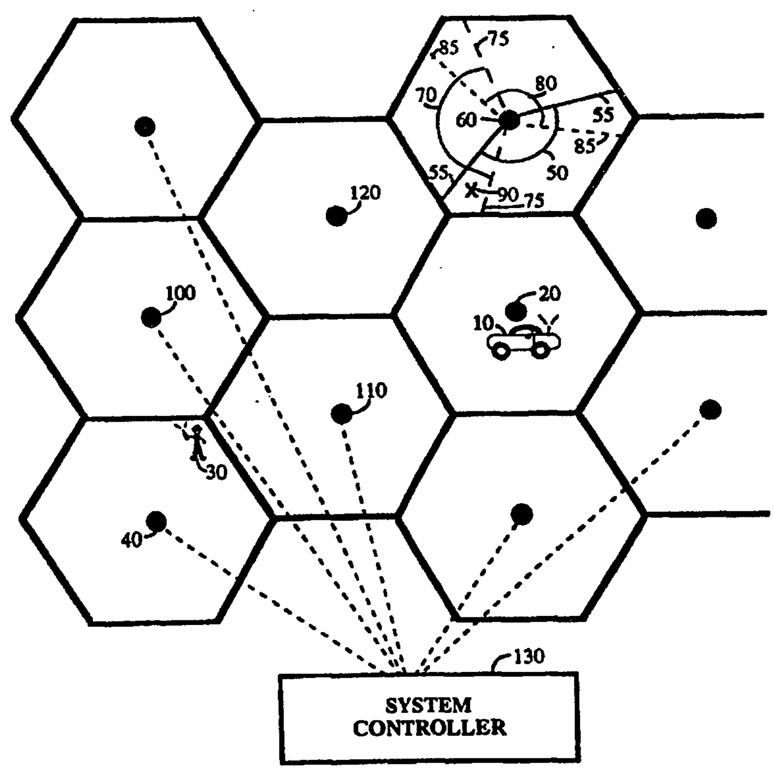
Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR REDUCING THE AVERAGE DOWNLINK TRANSMITTED POWER FROM BASE STATIONS DURING SOFT HANDOFF

(57) Abstract

A plurality of methods for achieving the soft or softer handoff process such that the performance of a system is improved. A first method is based on delaying the softer handoff process. A second method is based on reducing the power of transmissions from the sector having the weakest signal strength. A third method is based on eliminating transmissions from the sector having the weakest signal strength. A fourth method adds a new base station or sector only when the mobile unit is in need of additional power to operate properly. In all four methods, reverse link demodulation in each sector may continue with or without the transmission of the forward link. In all four methods the operation could be based on the signal strength of the reverse link signal or the forward link. It is also possible to combine two or more of these methods to create a hybrid method.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

Method and Apparatus for Reducing the Average Downlink Transmitted Power from Base Stations during Soft Handoff

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention is a Continuation-In-Part application of pending prior application Serial No. 08/144,901 filed on October 28, 1993 of Klein S. Gilhousen et al. for "METHOD AND APPARATUS FOR REDUCING THE AVERAGE TRANSMIT POWER OF A SECTORIZED BASE STATION" The present invention relates to communication systems, particularly to a plurality of methods for reducing the average transmit power from a sectorized base station.

II. Description of the Related Art

In a code division multiple access (CDMA) cellular telephone system, wireless local loop (WLL), satellite communication system such as GLOBALSTAR, or personal communications system (PCS), a common frequency band is used for communication with all base stations in a system. The common frequency band allows simultaneously communication between a mobile unit and more than one base station. Signals occupying the common frequency band are discriminated at the receiving station through the spread spectrum CDMA waveform properties based on the use of a high speed pseudonoise (PN) code. The high speed PN code is used to modulate signals transmitted from the base stations and the mobile units. Transmitter stations using different PN codes or PN codes that are offset in time produce signals that can be separately received at the receiving station.

In an exemplary CDMA system, each base station transmits a pilot signal having a common PN spreading code that is offset in code phase from the pilot signal of other base stations. During system operation, the mobile unit is provided with a list of code phase offsets corresponding to neighboring base stations surrounding the base station through which communication is established. The mobile unit is equipped with a searching element that allows the mobile unit to track the signal strength of the pilot signal from a group of base stations including the neighboring base stations.

A method and system for providing communication with the mobile unit through more than one base station during the handoff process are disclosed in U.S. Patent No. 5,267,261, issued November 30, 1993, entitled "MOBILE ASSISTED SOFT HANDOFF IN A CDMA CELLULAR TELEPHONE SYSTEM," assigned to the assignee of the present invention which is incorporated herein by this reference. Using this system, communication between the mobile unit and the end user is uninterrupted by the eventual handoff from an original base station to a subsequent base station. This type of handoff may be considered as a "soft" handoff in that communication with the subsequent base station is established before communication with the original base station is terminated. When the mobile unit is in communication with two base stations, a single signal for the end user is created from the signals from each base station by a cellular, WLL, GLOBALSTAR, or PCS controller.

Mobile unit assisted soft handoff operates based on the pilot signal strength of several sets of base stations as measured by the mobile unit. The Active Set is the set of base stations through which active communication is established. The Neighbor Set is a set of base stations surrounding an active base station comprising base stations that have a high probability of having a pilot signal strength of sufficient level to establish communication. The Candidate Set is a set of base stations having a pilot signal strength of sufficient level to establish communication.

When communications are initially established, a mobile unit communicates through a first base station and the Active Set contains only the first base station. The mobile unit monitors the pilot signal strength of the base stations of the Active Set, the Candidate Set, and the Neighbor Set. When a pilot signal of a base station in the Neighbor Set exceeds a predetermined threshold level, the base station is added to the Candidate Set and removed from the Neighbor Set at the mobile unit. The mobile unit communicates a message to the first base station identifying the new base station. A system controller decides whether to establish communication between the new base station and the mobile unit. Should the system controller decide to do so, the system controller sends a message to the new base station with identifying information about the mobile unit and a command to establish communications therewith. A message is also transmitted to the mobile unit through the first base station. The message identifies a new Active Set that includes the first and the new base stations. The mobile unit searches for the new base station transmitted information

signal and communication is established with the new base station without termination of communication through the first base station. This process can continue with additional base stations.

When the mobile unit is communicating through multiple base stations, it continues to monitor the signal strength of the base stations of the Active Set, the Candidate Set, and the Neighbor Set. Should the signal strength corresponding to a base station of the Active Set drop below a predetermined threshold for a predetermined period of time, the mobile unit generates and transmits a message to report the event. The system controller receives this message through at least one of the base stations with which the mobile unit is communicating. The controller may decide to terminate communications through the base station having a weak pilot signal strength.

The system controller upon deciding to terminate communications through a base station generates a message identifying a new Active Set of base stations. The new Active Set does not contain the base station through which communications are to be terminated. The base stations through which communication is established send the message to the mobile unit. The system controller also communicates information to the base station to terminate communications with the mobile unit. The mobile unit communications are thus routed only through base stations identified in the new Active Set.

Because the mobile unit is communicating with the end user though at least one base station at all times throughout the soft handoff processes, no interruption in communications occurs between the mobile unit and the end user. A soft handoff provides significant benefits in its inherent "make before break" communication over conventional "break before make" techniques employed in other cellular communication systems.

A typical cellular, WLL, GLOBALSTAR, or PCS system contains some base stations having multiple sectors. A multi-sectored base station comprises multiple independent transmit and receive antennas. The process of simultaneous communication with two sectors of the same base station is called softer handoff. The process of soft handoff and the process of softer handoff are the same from the mobile unit's perspective. However the base station operation in softer handoff is different from soft handoff. When a mobile unit is communicating with two sectors of the same base station, the demodulated data signals of both sectors are available for combination within the base station before the signals are passed to the

system controller. Because the two sectors of a common base station share circuitry and controlling functions, a variety of information is readily available to sectors of a common base station that is not available between independent base stations. Also two sectors of a common base station send the same power control information to a mobile unit (as discussed below). In satellite communication system such as GLOBALSTAR, most users will be in continuous softer handoff.

In a cellular, WLL, GLOBALSTAR, or PCS system, maximizing the capacity of the system in terms of the number of simultaneous telephone calls that can be handled is extremely important. System capacity in a spread spectrum system can be maximized if the transmitter power of each mobile unit is controlled such that each transmitted signal arrives at the base station receiver at the same level. In an actual system, each mobile unit may transmit the minimum signal level that produces a signal-to-noise ratio that allows acceptable data recovery. If a signal transmitted by a mobile unit arrives at the base station receiver at a power level that is too low, the bit-error-rate may be too high to permit high quality communications due to interference from the other mobile units. On the other hand, if the mobile unit transmitted signal is at a power level that is too high when received at the base station, communication with this particular mobile unit is acceptable but this high power signal acts as interference to other mobile units. This interference may adversely affect communications with other mobile units.

Path loss in the radio channel is defined as any degradation or loss suffered by a signal as it travels over-the-air and can be characterized by two separate phenomena: average path loss and fading. The forward link, i.e., the link from the base station to the mobile unit, typically but not necessarily operates on a different frequency than the reverse link, i.e., the link from the mobile unit to the base station. Nevertheless, because the forward and reverse link frequencies are within the same frequency band, a significant correlation exists between the average path loss of the two links. For example, a typically cellular system has one of its forward link channels centered about 882MHz paired with one of its reverse link channels centered about 837MHz. On the other hand, fading is an independent phenomenon for the forward link and reverse link and varies as a function of time. The characteristics of fading on the channel are the same, however, for both the forward and reverse link because the frequencies are within the

same frequency band. Therefore, the average of channel fading over time for both links is typically the same.

In an exemplary CDMA system, each mobile unit estimates the path loss of the forward link based on the total power at the input to the mobile unit. The total power is the sum of the power from all base stations operating on the same frequency assignment as perceived by the mobile unit. From the estimate of the average forward link path loss, the mobile unit sets the transmit level of the reverse link signal. Should the reverse link channel for one mobile unit suddenly improve compared to the forward link channel for the same mobile unit due to independent fading of the two channels, the signal as received at the base station from this mobile unit would increase in power. This increase in power causes additional interference to all signals sharing the same frequency assignment. Thus a rapid response of the mobile unit transmit power to the sudden improvement in the channel would improve system performance.

Mobile unit transmit power is also controlled by one or more base stations. Each base station with which the mobile unit is in communication measures the received signal strength from the mobile unit. The measured signal strength is compared to a desired signal strength level for that particular mobile unit. A power adjustment command is generated by each base station and sent to the mobile unit on the forward link. In response to the base station power adjustment command, the mobile unit increases or decreases the mobile unit transmit power by a predetermined amount. By this method, a rapid response to a change in the channel is effected and the average system performance is improved.

When a mobile unit is in communication with more than one base station, power adjustment commands are provided from each base station. The mobile unit acts upon these multiple base station power adjustment commands to avoid transmit power levels that may adversely interfere with other mobile unit communications and yet provide sufficient power to support communication from the mobile unit to at least one of the base stations. This power control mechanism is accomplished by having the mobile unit increase its transmit signal level only if every base station with which the mobile unit is in communication requests an increase in power level. The mobile unit decreases its transmit signal level if any base station with which the mobile unit is in communication requests that the power be decreased. A system for base station and mobile unit power control is disclosed in U.S. Patent No. 5,056,109 entitled "METHOD AND

APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM," issued October 8, 1991, assigned to the Assignee of the present invention.

Base station diversity at the mobile unit is an important consideration in the soft handoff process. The power control method described above operates optimally when the mobile unit communicates with each base station through which communication is possible, typically between one to three base stations although a greater number is possible. In doing so, the mobile unit avoids inadvertently interfering with communications through a base station receiving the mobile unit's signal at an excessive level but unable to communicate a power adjustment command to the mobile unit because communication is not established therewith.

As a mobile unit moves toward the edge of the base station coverage area, the signal strength of the forward link signal at the mobile unit falls. Also as the mobile unit moves to the edge of the coverage area of the current base station, the mobile unit generally moves closer to the base station coverage area of other base stations. Thus as the mobile unit moves toward the edge of the base station coverage area, the signal level from the current base station falls while interference from other base stations increases. The falling signal level also means that the signals are more sensitive to thermal noise and the noise created by the receiving circuitry in the mobile unit. This situation may be aggravated by a mobile unit located within an area where two sectors of a common base station overlap.

In a case where a set of base stations is operating at near capacity, the mobile unit located at the edge of the base station coverage area and within the coverage area of two sectors of the same base station may experience a drop in signal-to-noise ratio such that the quality of communications is degraded. The softer handoff process provides information to the base station that can be used to improve this situation. The improvement can be created by decreasing the average power transmitted by each sector of a base station. By decreasing the average power transmitted by each sector of a base station, the interference to all mobile units is reduced. Thus the interference to the mobile units at the edge of the coverage area is also reduced causing an increase in the average signal-to-noise ratio of mobile units a the edge of the coverage area.

In a system having soft and softer handoff capabilities and having neighboring base stations at or near capacity, a given amount of base station

power is divided among the forward link signals such that each additional forward link signal transmitted from a base station decreases the power of other forward link signals. In a system operating at capacity, compare a base station having two sectors in which every mobile unit in the coverage area of the base station is in softer handoff mode to a base station having two sectors in which no mobile unit is in softer handoff mode. In the base station having every mobile unit in softer handoff, each forward link signal from each sector is transmitted at one-half of the power of each forward link signal from the base station having no mobile unit in softer handoff. Because, in the case where every mobile unit is in softer handoff, the signals from each sector are combined in the mobile unit, the signal-to-interference ratio after combining is equal to the no handoff case if and only if each mobile unit is well served by both sectors. However, in reality not every mobile unit in softer handoff in a sectorized base station is well served by each sector.

The present invention is a technique which could be used to reduced the number of signal transmitted by a sector. A fewer number of signals to be transmitted from a sector means more power available for the remaining signals. When the base station transmits higher power forward link signals, the signal-to-interference for mobile units operating at handoff boundaries or at the edge of the coverage area is improved. Alternatively, as the number of signals is reduced, the total base station transmitter power can decrease which also results in less interference power in the system. These techniques can be used to reduce the number of mobile units in soft and softer handoff.

It is therefore the object of the present invention to improve forward link signal-to-interference ratio by reducing ineffectual forward link transmissions to mobile units in soft or softer handoff, reducing the interference power to other mobiles and making more transmitter power available to all useful links to mobile units.

It is therefore the object of the present invention to provide a plurality of methods to decrease the transmission power from a base station.

It is another object of the present invention to provide a plurality of methods to provide an enhanced softer handoff process to improve the forward link performance.

SUMMARY OF THE INVENTION

The present invention defines a plurality of methods for performing the soft or softer handoff process such that the performance of a system is improved. A first method is based on delaying the softer handoff process. When the mobile unit informs a first sector through which it is communicating that a second sector from the same base station has a signal strength sufficient to support communications, the base station commands the second sector to find the mobile unit transmitted signal. The base station does not command the mobile unit to establish communication with the second sector until the reverse link signal received at the second sector exceeds a predetermined threshold. Delaying the softer handoff reduces the average number of mobile units in the soft handoff process and reduces the average total power transmitted by each sector thus reducing the total average interference to mobile units in the system.

A second method is based on reducing the power of transmissions from the sector having the weakest signal strength. When the mobile unit informs a first sector through which it is communicating that a second sector from the same base station has a signal strength sufficient to support communications, the base station commands the second sector to establish communication with the mobile unit. The base station also commands the mobile unit to establish communication with the second sector. After the mobile unit enters the softer handoff mode, the base station compares the reverse link signal strength from each of the sectors. The base station reduces the forward link transmission power for that mobile unit from the sector having the weakest reverse link signal strength indication. Reducing transmission power from the weaker sector reduces the average power transmitted from each sector and therefore reduces interference to mobile units in the system.

A third method is based on eliminating transmissions from the sector having the weakest signal strength. When the mobile unit informs a first sector through which it is communicating that a second sector from the same base station has a signal strength sufficient to support communications, the base station commands the second sector to establish communication with the mobile unit. The base station also commands the mobile unit to establish communication with the second sector. After the mobile unit enters the softer handoff mode, the base station monitors the reverse link signal strength from each of the sectors. If the reverse link signal strength from one sector falls below a predetermined threshold for more than a predetermined period of time, the base station discontinues

forward link transmissions from the sector having the weakest signal strength indication. Discontinuing transmissions from the weaker sector reduces the average power transmitted from each sector and therefore reduces interference to mobile units in the system.

A fourth method is based on providing the mobile unit with a desired operation aggregate signal strength. The mobile unit provides to the base station a signal strength measurement from every base station that is a member of the Active and Candidates sets. The base station ranks the power levels in order of descending magnitude. The power levels are then summed in order until the desired operation aggregate signal strength is exceeded. The base station returns an Active Set message to the mobile unit identifying each base station corresponding to a signal strength used to reach the desired operation aggregate signal strength.

In all four methods above, reverse link demodulation in each sector may continue with or without the transmission of the forward link thus this method does not adversely effect reverse link performance or power control. In all four methods the operation could be modified such that the mobile unit informs the base station of received power on the forward link. The forward link power measurements from the mobile unit could be used as the criteria instead of the reverse link measurements made at the base station. It is also possible to combine two or more of these methods to create a hybrid method.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

Figure 1 is a diagram illustrating an exemplary base station coverage area structure;

Figure 2 is a block diagram illustrating an exemplary sectorized base station comprising multiple independent demodulation elements; and

Figure 3 is an exemplary representation of the coverage areas of three sectors of a sectorized base station.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates an exemplary base station coverage area structure. In such an exemplary structure, hexagonal base station coverage areas abut one another in a symmetrically tiled arrangement. Each mobile unit is located within the coverage area of one of the base stations. For example, mobile unit 10 is located within the coverage area of base station 20. In a code division multiple access (CDMA) cellular, wireless local loop (WLL), satellite communication system such as GLOBALSTAR, or personal communication (PCS) system, a common frequency band is used for communication with all base stations in a system allowing simultaneously communication between a mobile unit and more than one base station. Mobile unit 10 is located very close to base station 20 and therefore receives a large signal from base station 20 and relatively small signals from surrounding base stations. However mobile unit 30 is located in the coverage area of base station 40 but is close to the coverage area of base stations 100 and 110. Mobile unit 30 receives a relatively weak signal from base station 40 and similarly sized signals from base stations 100 and 110. Due to the decreased signal strength and the increased interference from neighboring base stations, mobile unit 30 has a lower overall signal to noise ratio with respect to base station 40 than mobile unit 10 has with respect to base station 20.

The exemplary base station coverage area structure illustrated in Figure 1 is highly idealized. In the actual cellular, WLL, GLOBALSTAR, or PCS environment, base station coverage areas may vary in size and in shape. Base station coverage areas may tend to overlap with coverage area boundaries defining coverage area shapes different from the ideal hexagon shape. Furthermore, base stations may also be sectored such as into three sectors, as is well known in the art. Base station 60 is shown as a three sectored base station. However base stations with a lesser or greater number of sectors are envisioned.

Base station 60 of Figure 1 represents an idealized three sectored base station. Base station 60 has three sectors, each of which covers more than 120 degrees of the base station coverage area. Sector 50, having a coverage area indicated by the unbroken lines 55, overlaps the coverage area of sector 70, having a coverage area indicated by the coarse dashed lines 75. Sector 50 also overlaps the sector 80, having a coverage area as indicated by the fine dashed lines 85. For example, location 90 as indicated by the X is located in both the coverage area of sector 50 and sector 70.

In general a base station is sectorized to reduce the total interference power to mobile units located within the coverage area of the base station while increasing the number of mobile units that can communicate through the base station. For example, sector 80 would not transmit a signal intended for a mobile unit at location 90 and thus no mobile unit located in sector 80 is significantly interfered with by the communication of a mobile unit at location 90 with base station 60.

However for a mobile unit positioned at location 90, the total interference has contributions from sectors 50 and 70 and from base stations 20 and 120. If the sum of the interference becomes too large, compared to the signal strength of the intended signal, communication between a mobile unit at location 90 and base station 60 may degrade. The present invention is a method for reducing the interference in such a case. In fact the present invention reduces the interference to all mobile units operating within a system of base stations.

The base stations 20, 40, 60, 100, and 120 shown in Figure 1 are controlled by system controller 130. Although Figure 1 shows only a subset of the connections between system controller 130 and the base stations, a connection between every base station and the system controller is implied. System controller 130 provides the control functions for each base station in the system. Among the control function is the coordination of the initiation and termination of soft handoff between base stations. When a mobile unit is in soft handoff between two or more base stations, a signal from the mobile unit is received at system controller 130 from each base station with which the mobile unit is in communication. System controller 130 performs the combination or selection of signals received from multiple base stations. System controller 130 also provides an interface to the public switch telephone network (PSTN) not shown.

Figure 2 illustrates an exemplary embodiment of a three sectored base station. In Figure 2, each of antennas 222A - 222C is the receive antenna for one sector and each of antennas 230A - 230C is the transmit antenna for one sector. Antenna 222A and antenna 230A correspond to a common coverage area and can ideally have the same antenna pattern. Likewise antennas 222B and 230B, and antennas 222C and 230C correspond to common coverage areas respectfully. Figure 2 represents a typical base station in that antennas 222A - 222C have overlapping coverage areas such that a single mobile unit signal may be present at more than one antenna at a time. Although only one receive antenna is shown for each sector,

typically two antennas are used for diversity with the receive signals combined for processing.

Figure 3 is a more realistic representation of the coverage areas of three sectors of a sectorized base station than base station 60 of Figure 1. Coverage area 300A, as represented by the finest line, corresponds to the coverage area of both antennas 222A and 230A. Coverage area 300B, as represented by the medium width line, corresponds to the coverage area of both antennas 222B and 230B. Coverage area 300C, as represented by the heaviest line, corresponds to the coverage area of both antennas 222C and 230C. The shape of the three coverage areas is the shape produced by standard directional dipole antenna. The edges of the coverage areas can be thought of as the location at which a mobile unit receives the minimum signal level to support communication through that sector. As a mobile unit moves into the sector, the signal strength increases. As a mobile unit moves past the edge of the sector, communication through that sector may degrade. A mobile unit operating in softer handoff mode is likely to be located in the overlapped region of two coverage areas.

Referring again to Figure 2, antennas 222A, 222B, and 222C supply the received signal to receive processings 224A, 224B, and 224C respectively. Receive processings 224A, 224B, and 224C process the RF signal and convert the signal to digital bits. Receive processings 224A, 224B, and 224C filter the digital bits and provide the resulting digital bits to interface port 226. Interface port 226 may connect any of the three incoming signal paths to any of the demodulation elements 204A - 204N under the control of controller 200 through interconnection 212.

Demodulation elements 204A - 204N are also controlled by controller 200 through interconnection 212. Controller 200 assigns demodulation elements 204A - 204N to one of the plurality of information signals from a single mobile unit from any one of the sectors. Demodulation elements 204A - 204N produce data bits 220A - 220N each representing an estimate of the data from the single mobile unit. Data bits 220A - 220N are combined in symbol combiner 208 to produce a single estimate of the data from the mobile unit. The output of symbol combiner 208 is aggregate soft decision data suitable for Viterbi decoding. Notice that symbol combiner 208 can combine signals from just one sector to produce an output or it can combine symbols from multiple sectors as selected by the interface port 226. Each one of demodulation elements 204A - 204N measures a signal strength estimation of the signal

that it is demodulating and provides the estimation to controller 200. A single power adjustment command is created from the estimated signal strengths independent of the sector through which the signal is received. Thus each sector in the base station transmits the same power adjustment command to a single mobile unit.

When symbol combiner 208 is combining signals from a mobile unit that is communicating through more than one sector, the mobile unit is in softer handoff. The base station may send the output of symbol combiner 208 to a decoder and then to a cellular, WLL, GLOBALSTAR, or PCS system controller. A system controller may receive decoded symbols from a common mobile unit from multiple base stations and produce a single output. This process is referred to as soft handoff.

Demodulation elements 204A - 204N also provide several output control signals to controller 200 through interconnection 212. The information passed to controller 200 includes an estimate of the signal strength of the signal assigned to a particular demodulator. Typically this information is not passed to the system controller. Therefore sectors of a common base station demodulating signals from a common mobile unit are much more intimately related than two base stations sending signals to a common system controller. The intimacy of the relationship of two sectors supporting a softer handoff mode with a single mobile unit provides the basis for the first three methods of the present invention.

In many applications, an actual base station also comprises at least one searcher element. The searcher element is also capable of demodulating a signal and is used to continually scan the time domain in search of available signals. The searcher element identifies a set of available signals and passes the information to the controller. The controller may use the set of available signals to assign or re-assign the demodulation elements to the most advantageous signals available. The placement of the searcher element is the same as the placement of the demodulating elements in Figure 2. As such the searcher elements may also be assigned to a signal from a plurality of sectors of a common base station. In the most general case, demodulation elements 204A - 204N can be assumed to comprise some elements that are capable of performing the searching function.

The transmit process shown in Figure 2 receives a message for a mobile unit from the end user through the system controller. The message can be sent on one or more of antennas 230A - 230C. Interface port 236 connects the message for the mobile unit to one of more of modulation

elements 234A - 234C as set by controller 200. Modulation elements 234A - 234C modulate the message for the mobile unit with the appropriate PN code. The modulated data from modulation elements 234A - 234C is passed to transmit processing 232A - 232C respectively. Transmits processings 232A - 232C convert the message to an RF frequency and transmit the signal at an appropriate signal level through antennas 230A - 230C respectively. Notice that interface port 236 and interface port 226 operate independently in that receiving a signal from a particular mobile unit through one of antennas 222A - 222C does not necessarily mean that the corresponding transmit antenna 230A - 230C is transmitting a signal to the particular mobile unit. Also note that the power adjustment commands sent through each antenna is the same, thus sector diversity in a common base station is not critical for the optimal power control performance.

The handoff process as described in U.S. Patent No. 5,056,109 referred to above, describes a process that is summarized in the following steps.

Normal operation of softer handoff:

1: Mobile unit is communicating with base station X through sector alpha antenna meaning base station X, sector alpha is identified as a member of the Active Set.

2: Mobile unit monitors the pilot signal from base station X, sector beta antenna and base station X, sector beta is identified as a member of the Neighbor Set. The pilot signal strength from base station X, sector beta antenna exceeds a predetermined threshold.

3: Mobile unit identifies base station X, sector beta as a member of the Candidate Set and informs base station X through sector alpha antenna.

4: Base station X establishes the availability of resources in sector beta.

5: Sector beta antenna begins to receive a reverse link signal from mobile unit.

6: Sector beta antenna begins to transmit a forward link signal to mobile unit.

7: Base station X through sector alpha antenna updates the mobile unit Active Set to identify base station X, sector beta.

8: Mobile unit establishes communication with base station X, sector beta antenna. Mobile unit combines the signals from sector alpha antenna and sector beta antenna.

9: Base station X combines the signals from mobile unit received through sector alpha antenna and sector beta antenna (softer handoff).

The first method to reduce the number of mobile units in the softer handoff mode is based on delaying the softer handoff process. The process inserts an additional step between steps 5 and 6 that we will label step 5.1. Step 5.1 adds the additional function as follows:

5.1: Determine the signal strength of the reverse link signal from the mobile unit. Pause the process at this step until the reverse link signal strength exceeds a predetermined threshold.

Step 5.1 delays the onset of softer handoff thus reducing the total number of forward link transmissions. Even while the forward link transmissions are delayed, the reverse link signal received by sector beta may be combined with the reverse link signal from sector alpha.

Referring again to Figure 3, suppose a mobile unit follows the path indicated the arrow. At point 302, the mobile unit enters the coverage area of sector 300B from sector 300A. At this point, sector 300B would be moved from the Neighbor Set to the Candidate Set. The mobile unit informs the base station of the new addition to the Candidate Set. If resources are available in sector 300B, sector 300B begins to receive the reverse link signal from the mobile unit. Sector 300B does not begin to transmit a signal and instead monitors the reverse link signal from the mobile unit. As the mobile unit moves further into sector 300B, the signal strength from the mobile unit as received by sector 300B increases. Suppose at point 304 the signal strength of the received signal exceeds the predetermined threshold of step 5.1. The process continues and sector 300B begins to transmit a forward link signal to the mobile unit. Sector 300A updates the mobile unit Active Set to include sector 300B.

Note that this method does not degrade the advantages of softer handoff and the make-before-break handoff process. In Figure 3, as the mobile unit continued to travel along the arrow, the mobile unit would be in a softer handoff state from point 304 until point 306. At point 306, communication with sector 300A can be terminated because the mobile unit is no longer within the coverage area of sector 300A. Without the addition of step 5.1, the mobile unit would be in softer handoff from point 302 to point 306.

This first method could be modified to achieve similar results by basing the delay on the signal strength of the forward link signal as measured at the mobile unit. The modified step 5.1 would be as follows:

5.1: Determine the signal strength of the pilot signal at the mobile unit from sector beta antenna. Pause the process at this step until the pilot signal strength exceeds a predetermined threshold.

The transfer of the pilot signal strength could automatically be transmitted from the mobile unit as part of the notification of a new entry in the Candidate Set. The mobile unit could transmit the signal strength periodically or mobile unit could respond to a request for the signal strength from the base station. The mobile unit could be aware of the threshold and notify the base station when the pilot signal strength exceeds the predetermined level.

No matter which variation of first method is used, the average transmission power from each sector is reduced. By delaying the forward link transmissions to the set of mobile units that are in the coverage area of a first sector and have not deeply penetrated the coverage area of a second sector, each mobile unit is subjected to a decrease amount of interference on the forward link. Notice that this method does not effect soft handoff (handoff between two independent base stations).

The second method involves reducing the power of the forward link transmission. The original steps 1 through 9 above would remain the same. An additional two steps would be added following step 9 as follows:

10: Determine the reverse link signal strength received through each sector antenna.

11: Reduce the power of the transmitted forward link signal by a predetermined amount from the sector antenna having the weakest reverse link signal.

Alternatively the same steps could be executed based on the forward link transmission power as follows:

10: Determine the forward link signal strength received from each sector at the mobile unit and provide this information to the base station.

11: Reduce the power of the transmitted forward link signal by a predetermined amount from the sector antenna having the weakest forward link signal as measured at the mobile unit.

No matter which variation of the second method is used, the average transmission power from each sector is reduced. By reducing the forward link transmissions to a set of mobile units that are in the coverage area of two sectors, each mobile unit in the two sectors is subjected to a decrease amount of interference on the forward link. Again this method does not effect soft handoff.

A potential unfavorable consequence to this method exists. The mobile unit may combine signals from two sectors based on the pilot signal strength from each of the sectors as received at the mobile unit. Therefore the mobile unit is assuming a fixed relationship between the strength of the pilot signal from a sector and the strength of the information signal intended specifically for the mobile unit. When the power of the transmitted information signal is reduced, the combination ratio will be unbalanced by some amount. The unbalance causes the combination process to operate with non-optimal performance. If the reduction ratio is small, for instance if the power intended for the mobile unit is reduced by about 3dB, this effect may be negligible. This problem could be fixed by having the base station inform the mobile unit of the relation between pilot signal strength and information signal strength. The mobile could respond to this information by appropriately modifying the combiner ratio to reflect the change.

A third method adds new steps 10 and 11 to the original steps 1 through 9 as follows:

10: Monitor the received reverse link signal at each sector antenna. When the reverse link signal falls below a threshold for a predetermined period of time at a sector antenna, inform the mobile unit to stop demodulating the forward link signal from the weak sector antenna.

11: Stop sending the forward link signal to the mobile unit from the weak sector antenna.

12: Return to step 5.

Alternatively the same steps could be executed based on the forward link transmission power as follows:

10: Determine the forward link signal strength level received from each sector antenna at the mobile unit and provide this information to the base station.

11: When the forward link signal from a sector antenna falls below a threshold for a predetermined period of time, inform the mobile unit to stop demodulating the forward link signal from the weak sector antenna.

12: Stop transmitting the forward link signal from the weak sector antenna.

No matter which variation of the third method is used, the average transmission power from a sector is reduced. By terminating the forward link transmissions to the set of mobile units in the coverage area of two sectors before signal strength would mandate termination, each mobile unit in both sectors is subjected to a decrease in interference power on the forward link. Notice that neither alternative to the third method requires the weak sector to discontinue demodulating the reverse link signal from the mobile unit. Again this method does not effect soft handoff.

The fourth method can be used in a manner similar to the first three methods to reduce the average transmission power from a base station. The advantage of the fourth method is that it is equally applicable to soft and softer handoff. In order to function optimally, a mobile unit must receive a desired operation aggregate signal strength. The desired operation aggregate signal strength is calculated as the sum the signal strengths of each signal being demodulated by a mobile unit. If more than the minimum aggregate signal strength is demodulated by a mobile unit, the additional power does not improve the link significantly. The additional power above the aggregate signal strength does however cause interference to other mobile units. The fourth method is based on eliminating the additional signal strength above the desired operation aggregate signal strength to each mobile unit.

The handoff process of the fourth method is summarized in the following steps.

1: Mobile unit is communicating with base station X through sector alpha antenna meaning base station X, sector alpha is identified as a member of the Active Set.

2: Mobile unit monitors the pilot signal from base station Y, sector beta antenna and base station Y, sector beta is identified as a member of the Neighbor Set. The pilot signal strength from base station Y, sector beta antenna exceeds a predetermined threshold.

3: Mobile unit identifies base station Y, sector beta as a member of the Candidate Set and informs base station X through sector alpha antenna. Mobile unit transmits the signal strength it perceives from base station X,

sector alpha, base station Y, sector beta, and any other base stations with which the mobile unit is in communication.

4: Base station X passes the signal strength information to the system controller. The system controller sums the signal strengths together in rank order beginning with the largest signal strength until all are summed together or until the desired operation aggregate signal strength is exceeded.

5: If base station Y, sector beta corresponds to one of the signal strengths used in the sum, the system controller designates a new Active Set comprising base station Y, sector beta.

6: Base station Y, sector beta antenna begins to transmit a forward link signal to mobile unit.

7: Base station X through sector alpha antenna updates the mobile unit Active Set to identify base station Y, sector beta.

8: Mobile unit establishes communication with base station Y, sector beta antenna. Mobile unit combines the signals from base station X, sector alpha antenna and base station Y, sector beta antenna.

9: System controller combines or selects between the signal received from base station X, sector alpha, base station Y, sector beta, and any other base station through which communication is established with the mobile unit.

In this manner, a new base station is only added to the Active Set if it is needed to provide the mobile unit with the desired operation aggregate signal strength for optimal performance. As with the other methods, reverse link demodulation in each sector or base station may continue with or without the transmission of the forward link.

When the fourth method as enumerated above does not add base station Y, sector beta in step 5, an alternative stimulus in addition to that listed in step 2 is needed to provide the stimulus to initiate the process at step 3. In the preferred embodiment, at least three different stimulus may exist. First, the mobile unit informs the base station whenever the signal strength of a member of the Candidate Set exceeds the signal strength of any member of the Active Set. Upon receiving such a message, the process resumes with step 3. Also the mobile unit may repeatedly send the base station a list of the signal strengths of the members of the Active Set as a power measurement report message. In the preferred embodiment, as the total aggregate power of the Active Set decreases, the power measurement report message is sent more often. When the total aggregate power falls below a threshold, the base station can request a Candidate and Active Set

signal strength measurement message in which the mobile unit informs the base station of the signal strength of each base station in the Active and Candidate Sets. Upon receiving such a message, the process resumes with step 4. Additionally the base station may request a Candidate and Active Set signal strength measurement message at any time due to some stimulus in the base station and the process may resume with step 4.

Using the fourth method, if a mobile unit in communication with a first and a second base stations enters the coverage area of a third base station, it provides the signal strength received from each of the three base stations to the system controller. If the signal strength of the new base station exceeds the signal strength of one of the two base stations with which communication is established and communication through two base stations is required to provide the mobile unit with the desired operation aggregate signal strength, the next Active Set message from the system controller designates the largest of the two previously active base stations and the new base station thus indicating that communication be terminated through a base station and established with another with the use of one message. In actual implementations the new base station's signal strength would need to exceed the currently active base station's signal strength by some reasonable gating amount. The system operates most effectively when the system is not 'ping ponging' communications between two base stations. The reasonable gating amount acts as hysteresis to prevent the ping pong situation.

There are many variations to the fourth method. The example above was described in terms of sectors of different base stations. The same method applies to sectors of a common base station and to unsectorized base stations. The functionality of the base station and system controller could be divided in many ways. An analogous method may be based on reverse link signal as perceived by the base stations or it could be based on other factors such as signal to noise ratio, frame erasure rate, and bit error rate. The fourth method may be elegantly coupled to one of the first three methods.

An analogous method could be used to remove a base station from the Active Set. Removing a base station from the Active Set as described in U.S. Patent No. 5,267,261 is also mobile unit assisted. The mobile unit monitors the signal strength of each base station through which communication is established. If the signal strength from a base station in the Active Set falls below a threshold for some period of time, the mobile unit informs the base stations through which it is communicating and at

least one base station responds by sending a new Active Set to the mobile unit which does not comprise the base station corresponding to the weak signal.

Applying the principles of the fourth method to the process of removing a base station from the Active Set is summarized in the following steps:

1: Mobile unit is communicating with base station X through sector alpha antenna and base station Y through sector beta antenna meaning base station X, sector alpha and base station Y, sector beta are identified as members of the Active Set.

2: Mobile unit transmits the signal strength it perceives from base station X, sector alpha, base station Y, sector beta, and any other base stations with which the mobile unit is in communication.

3: At least base station X passes the signal strength information to the system controller. The system controller sums the power levels together in rank order beginning with the largest signal strength until all are summed together or until the desired operation aggregate signal strength is exceeded.

4: If base station Y, sector beta does not correspond to one of the signal strengths used in the sum, the system controller designates a new Active Set that does not comprise base station Y, sector beta.

5: At least base station X, sector alpha antenna sends the mobile unit the new Active Set.

6: Base station Y, sector beta antenna terminates transmission of a forward link signal to mobile unit.

The fourth method as applied to removing a base station can also work from the same three variety of stimulus as described above for the process of adding a base station. For example, even if the signal strength received from base station Y, sector beta remains well above the communications threshold, it may be advantages to terminate communication through base station Y, sector beta if the mobile unit receives sufficient power from the other base stations with which it is in communication. Any time a list of the signal strengths of the members of the Active Set is sent from the mobile unit to the base station, the removal process of the fourth method may be executed. In the most efficient preferred embodiment, the addition and removal process of the fourth method are combined into one efficient process.

Each of the four methods defined herein may be combined with one or more of the other methods. Also there are many obvious variations of the embodiments of methods 1, 2, 3, and 4 including the simple rearrangement of steps within each method. The signal strength measurements made by the mobile units and base stations could be replaced by other criteria such as signal to noise ratio, frame erasure rate, and bit error rate. The previous example is based on the use of a pilot signal on the forward link. Signal strength measurements could be the measurement of signals other than a pilot signal whether or not the system comprises a pilot signal.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WE CLAIM:

CLAIMS

1. In a spread spectrum communication system in which a mobile unit user communicates with another system user via at least one base station in a system of base stations as directed by a system controller, a method for directing communications between said mobile unit user and said system of base stations comprising the steps of:

communicating by said mobile unit with a first base station wherein said first base station has an entry on a first list in said mobile unit wherein said first list comprises an entry for each base station with which active communication is established;

measuring at said mobile unit signal strength transmitted by a second base station through which active communication is not established;

providing by said mobile unit to said system controller a measured signal strength of said first base station and said measured signal strength of said second base station; and

comparing at said system controller said measured signal strength of said first base station to a desired operating power and sending said mobile unit a new first list comprising said second base station if said measured signal strength of said first base station is less than said desired operating power and said mobile unit is not in communication with any other base station.

2. The method of claim 1 wherein each base station in said system of base stations transmits a pilot signal and wherein said measured signal strength of said second base station is a measurement of signal strength of said pilot signal transmitted by said second base station.

3. The method of claim 1 further comprising the steps of:

communicating by said mobile unit with a third base station wherein said third base station has an entry on said first list;

providing by said mobile unit to said system controller a measured signal strength of said third base station wherein said measured signal strength of said third base station is less than said measured signal strength of said first base station;

summing at said base station said measured signal strength of said first base station and said measured signal strength of said third base station; and

comparing said summed measured signal strength of said first and third base stations to said desired operating power and sending said mobile unit a new first list comprising an entry corresponding to said second base station if said summed measured signal strength of said first and third base stations is less than said desired operating power.

4. The method of claim 1 further comprising the steps of:

communicating by said mobile unit with a third base station wherein said third base station has an entry on said first list;

providing by said mobile unit to said system controller a measurement of signal strength of said third base station wherein said measured signal strength of said third base station is less than said measured signal strength of said first and second base stations; and

sending said mobile unit a new first list comprising an entry corresponding to said second base station if said measured signal strength of said first base station is less than said desired operating power.

5. The method of claim 4 wherein said measured signal strength of said third base station is less than said measured signal strength of said first and second base stations by a predetermined threshold amount.

6. The method of claim 4 further comprising the steps of:

summing at said system controller said measured signal strength of said first base station and said measured signal strength of said second base station; and

sending said mobile unit a new first list comprising an entry corresponding to said third base station only if said sum of said measured signal strengths of said first and second base stations is less than said desired operating power.

7. The method of claim 1 wherein said first base station and said second base stations are two different sectors of a common base station cell site.

8. The method of claim 1 wherein said first base station is a multisectored base station and wherein said measured signal strength of said first base station corresponds to a signal strength from a single sector thereof.

9. The method of claim 1 wherein said step of providing by said mobile unit to said system controller said measured signal strength of said first base station and said measured signal strength of said second base station is performed because said measured signal strength of said second base station exceeds said measured signal strength of said first base station.

10. The method of claim 1 wherein said step of providing by said mobile unit to said system controller said measured signal strength of said first base station and said measured signal strength of said second base station is performed periodically at a variable rate.

11. The method of claim 10 wherein said variable rate is a function of a rate at which of frame errors occur.

12. The method of claim 1 wherein said step of providing by said mobile unit to said system controller said measured signal strength of said first base station and said measured signal strength of said second base station is performed in response to a request from said system controller.

13. The method of claim 1 wherein said step of providing by said mobile unit to said system controller said measured signal strength of said first base station and said measured signal strength of said second base station is performed because said measured signal strength of said second base station exceeds a predetermined threshold.

14. The method of claim 1 further comprising the step of receiving and demodulating at said second base station an information signal transmitted by said mobile unit independent of whether said second base station has an entry on said first list or said new first list.

15. In a spread spectrum communication system in which a mobile unit user communicates with another system user via at least one base station in a system of base stations as directed by a system controller, a method for directing communications between said mobile unit user and said system of base stations comprising the steps of:

communicating by said mobile unit with a first base station wherein said first base station has an entry on a first list in said mobile unit wherein said first list comprises an entry for each base station with which active communication is established;

measuring at said mobile unit signal strength transmitted by a second base station;

comparing said measured signal strength of said second base station to a first predetermined level;

providing by said mobile unit to said system controller a measurement of signal strength of said first base station and said second base station if said measured signal strength of the second base station exceeds said first predetermined level; and

comparing at said system controller said measured signal strength of said first base station to a desired operating power and sending said mobile unit a new first list comprising said second base station if said measured signal strength of said first base station is less than said desired operating power and said mobile unit is not in communication with any other base station.

16. In a spread spectrum communication system in which a mobile unit user communicates with another system user via at least one base station in a system of base stations as directed by a system controller, a method for directing communications between said mobile unit user and said system of base stations comprising the steps of:

communicating by said mobile unit with a first base station wherein said first base station has an entry on a first list in said mobile unit wherein said first list comprises an entry for each base station with which active communication is established;

measuring at said mobile unit a communication quality index corresponding to a second base station wherein said second base station does not have an entry on said first list;

providing by said mobile unit to said system controller a measured quality index of said first base station and said measured quality index of said second base station; and

comparing at said system controller said measured quality index of said first base station to a desired operating index and sending said mobile unit a new first list comprising said second base station if said measured signal strength of said first base station does not meet said desired operating index.

17. The method of claim 16 wherein said measured quality index of said first and second base stations is a frame erasure rate.

18. The method of claim 16 wherein said measured quality index of said first and second base stations is a signal to noise ratio.

19. The method of claim 16 wherein said measured quality index of said first and second base stations is a bit error rate.

20. A method for improving the signal-to-interference ratio in a communication system having a set of base stations with at least one base station comprised of multiple sectors comprising the steps of:

establishing communication between a mobile unit and a first sector of said base station;

establishing communication between said mobile unit and a second sector of said base station;

measuring signal strength of a signal from said mobile unit received through said first sector;

measuring signal strength of a signal from said mobile unit received through said second sector;

comparing the signal strength of said signal from said mobile unit received through said first sector and the signal strength of said signal from said mobile unit received through said second sector to identify the sector receiving the weakest signal of said signals from said mobile unit received through said first and said second sector; and

reducing signal strength of a signal from said identified sector to said mobile unit.

21. A method for reducing interference in a communication system having a base station comprised of multiple sectors comprising the steps of:

receiving through a first sector antenna of said base station a first signal from a mobile unit;

receiving through a second sector antenna of said base station a second signal from said mobile unit;

transmitting through said first sector antenna a third signal to said mobile unit;

transmitting through said second sector antenna a fourth signal to said mobile unit;

measuring the signal strength of said first signal;

measuring the signal strength of said second signal wherein the signal strength of said second signal is less than the signal strength of said first signal; and

terminating the transmission of said fourth signal.

22. A method for reducing interference in a communication system having a base station comprised of multiple sectors comprising the steps of:

receiving through a first sector antenna of said base station a first signal from a mobile unit;

receiving through a second sector antenna of said base station a second signal from said mobile unit;

transmitting through said first sector antenna of said base station a third signal to said mobile unit;

transmitting through said second sector antenna of said base station a fourth signal to said mobile unit;

measuring the signal strength of said third signal at said mobile unit;

measuring the signal strength of said fourth signal at said mobile unit wherein the signal strength of said fourth signal is less than the signal strength of said third signal;

providing by said mobile unit said signal strength of said third and fourth signals to said base station; and

terminating the transmission of said fourth signal.

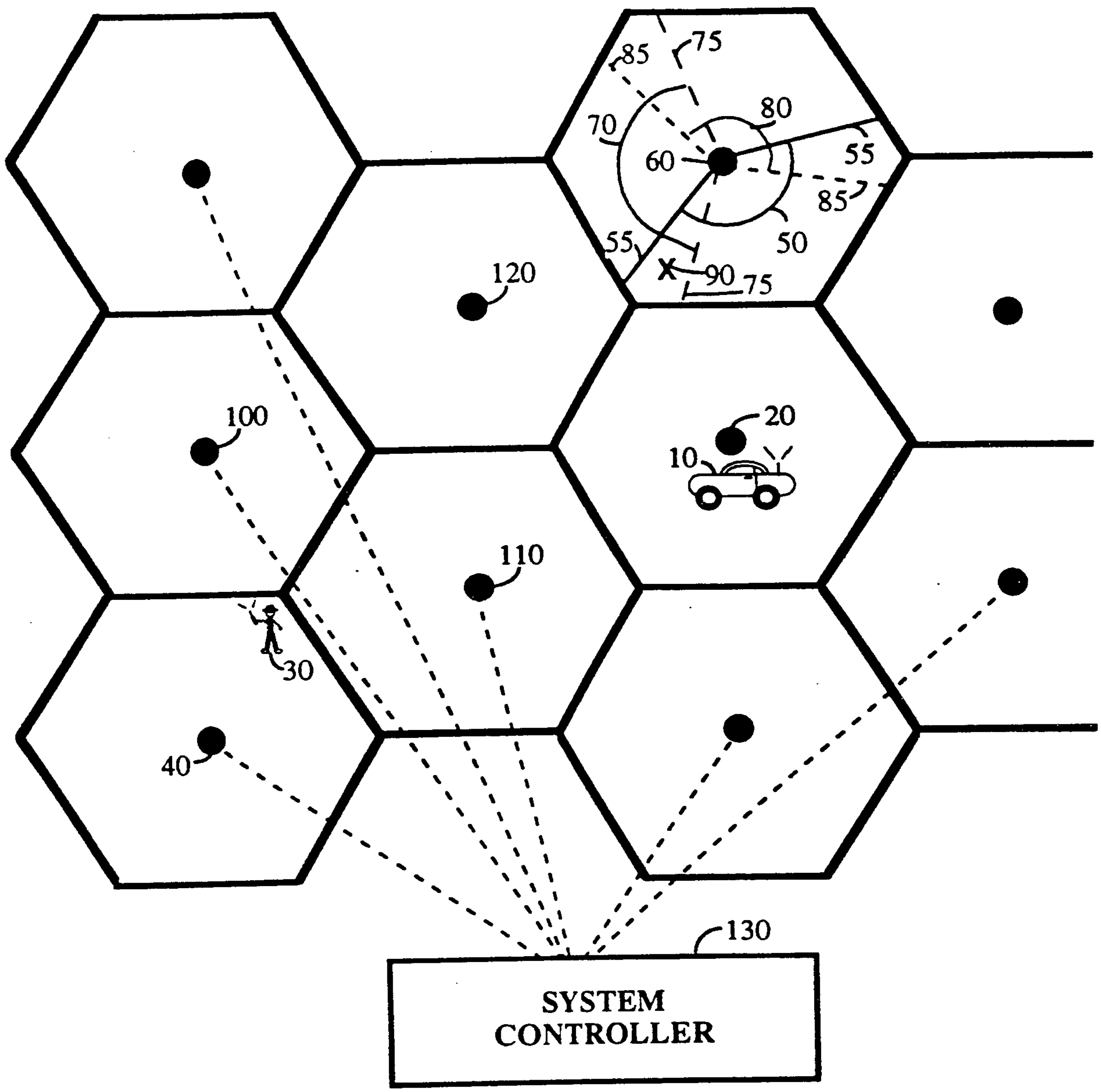

85
75
70
80
60
55
85
50
55
90
75
120
100
20
10
110
30
40
130
SYSTEM CONTROLLER

FIG. 1

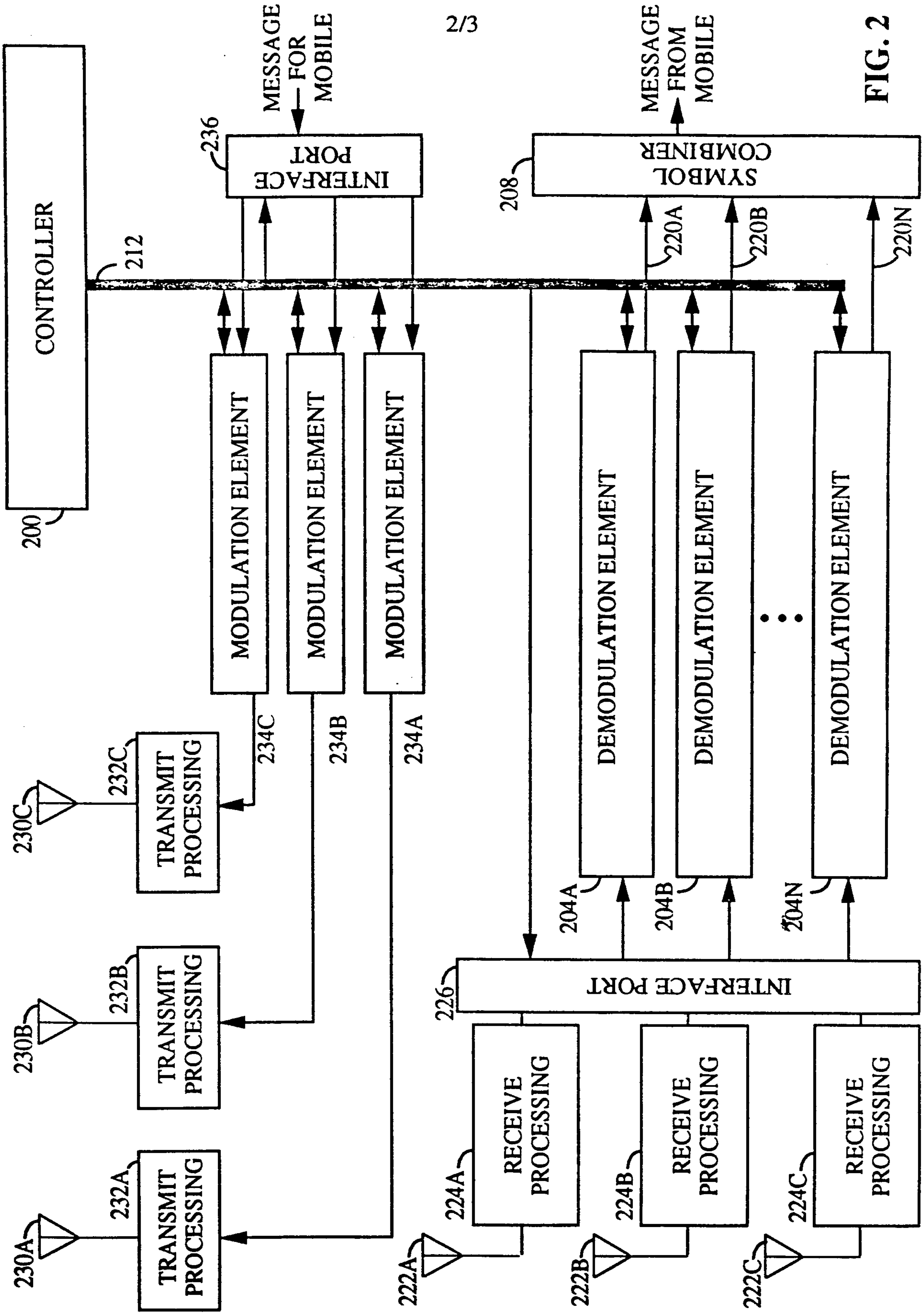

CONTROLLER
200
212
MESSAGE FOR MOBILE
INTERFACE PORT
236
SYMBOL COMBINER
208
MESSAGE FROM MOBILE
220A
220B
220N
MODULATION ELEMENT
MODULATION ELEMENT
MODULATION ELEMENT
234C
234B
234A
DEMODULATION ELEMENT
DEMODULATION ELEMENT
DEMODULATION ELEMENT
204A
204B
204N
TRANSMIT PROCESSING
TRANSMIT PROCESSING
TRANSMIT PROCESSING
232C
232B
232A
230C
230B
230A
INTERFACE PORT
226
RECEIVE PROCESSING
RECEIVE PROCESSING
RECEIVE PROCESSING
224A
224B
224C
222A
222B
222C

FIG. 2

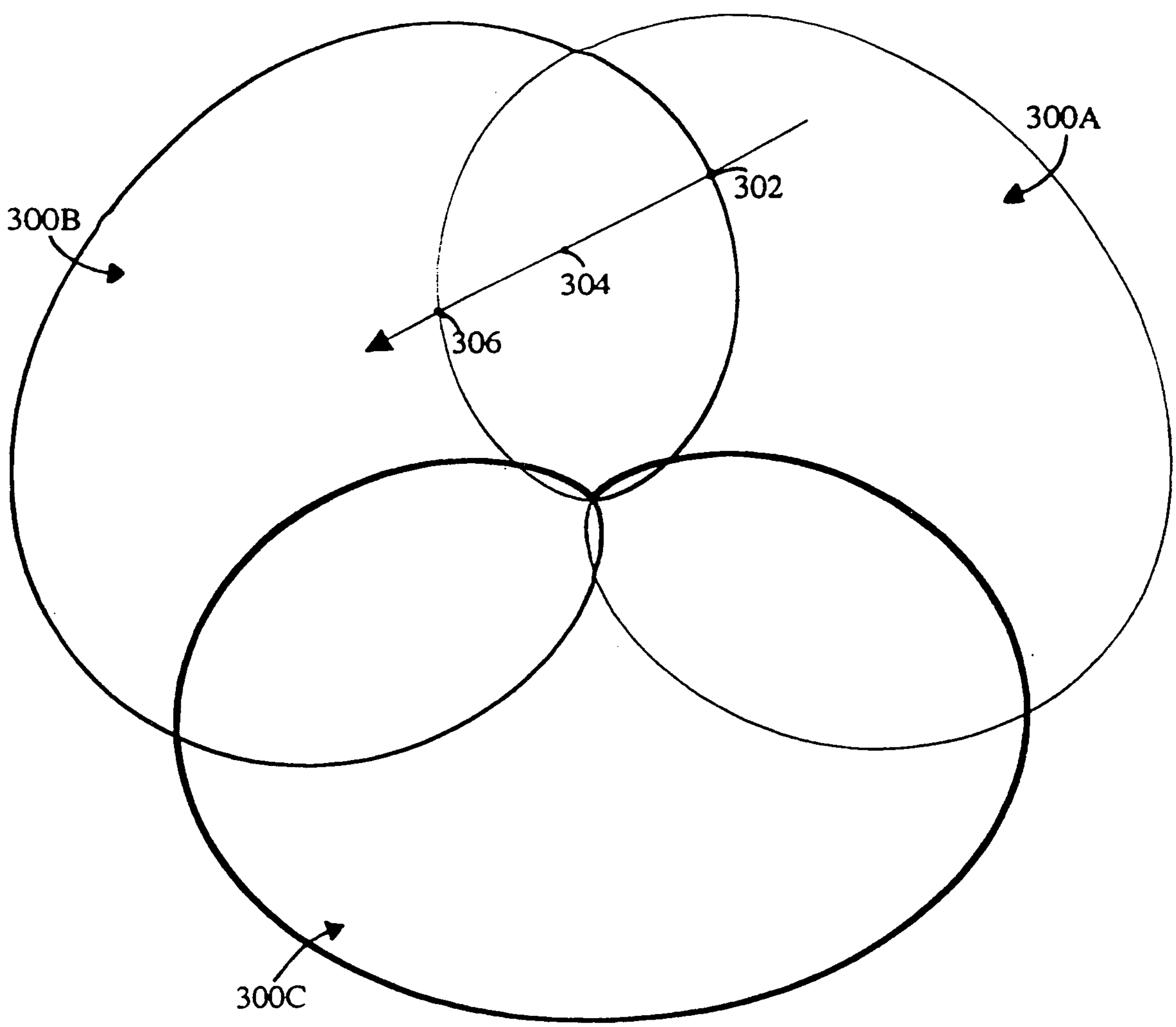


FIG. 3

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04Q 7/38, H04L 5/06

A1

(11) International Publication Number: WO 97/01256

(43) International Publication Date: 9 January 1997 (09.01.97)

(21) International Application Number: PCT/SE96/00814

(22) International Filing Date: 20 June 1996 (20.06.96)

(30) Priority Data:
08/493,489 22 June 1995 (22.06.95) US

(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE).

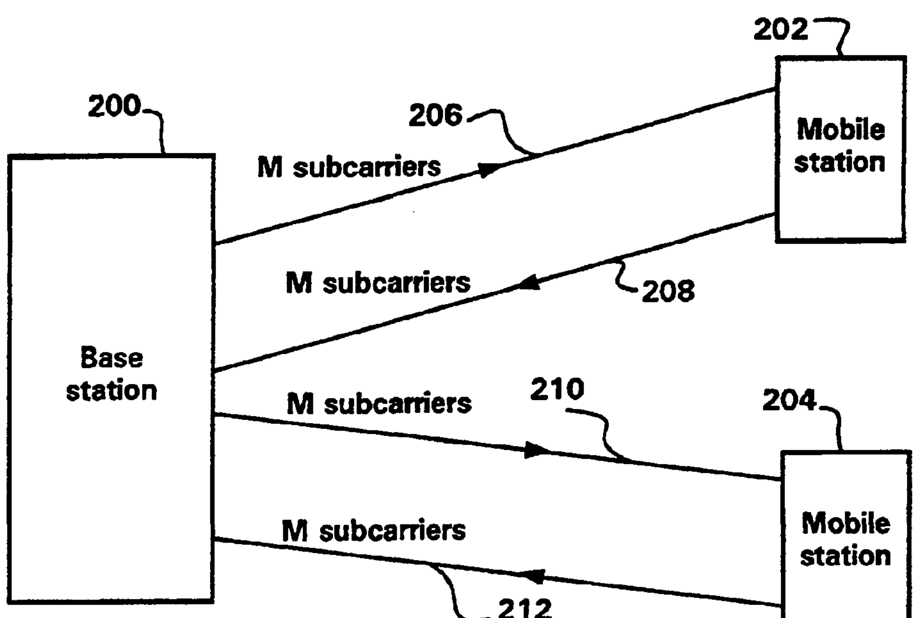
(72) Inventors: FRODIGH, Carl, Magnus; Langelandsgatan 43, 1 tr, S-164 43 Kista (SE). GUDMUNDSON, Perols, Leif, Mikael; Koldinggatan 4, 2 tr, S-164 46 Kista (SE).

(74) Agents: BOHLIN, Björn et al.; Telefonaktiebolaget LM Ericsson (publ), Patent and Trademark Dept., S-126 25 Stockholm (SE).

(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: ADAPTIVE CHANNEL ALLOCATION IN A FREQUENCY DIVISION MULTIPLEXED SYSTEM



(57) Abstract

A method and system of adaptive channel allocation in a frequency division multiplexed system is provided. In the method and system, a subset of M subcarriers is chosen from a larger set of N subcarriers available for communications on a link. As communications take place on the link, signal quality (C/I) measurements (342) on the subcarriers of the subset of M subcarriers and interference (I) measurements (344) on the subcarriers of the group of N subcarriers are periodically performed. The C/I and I measurements are then used to reconfigure (422) the subset of M subcarriers to reduce co-channel interference on the link.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	**GB**	United Kingdom	**MW**	Malawi
AT	Austria	**GE**	Georgia	**MX**	Mexico
AU	Australia	**GN**	Guinea	**NE**	Niger
BB	Barbados	**GR**	Greece	**NL**	Netherlands
BE	Belgium	**HU**	Hungary	**NO**	Norway
BF	Burkina Faso	**IE**	Ireland	**NZ**	New Zealand
BG	Bulgaria	**IT**	Italy	**PL**	Poland
BJ	Benin	**JP**	Japan	**PT**	Portugal
BR	Brazil	**KE**	Kenya	**RO**	Romania
BY	Belarus	**KG**	Kyrgystan	**RU**	Russian Federation
CA	Canada	**KP**	Democratic People's Republic	**SD**	Sudan
CF	Central African Republic		of Korea	**SE**	Sweden
CG	Congo	**KR**	Republic of Korea	**SG**	Singapore
CH	Switzerland	**KZ**	Kazakhstan	**SI**	Slovenia
CI	Côte d'Ivoire	**LI**	Liechtenstein	**SK**	Slovakia
CM	Cameroon	**LK**	Sri Lanka	**SN**	Senegal
CN	China	**LR**	Liberia	**SZ**	Swaziland
CS	Czechoslovakia	**LT**	Lithuania	**TD**	Chad
CZ	Czech Republic	**LU**	Luxembourg	**TG**	Togo
DE	Germany	**LV**	Latvia	**TJ**	Tajikistan
DK	Denmark	**MC**	Monaco	**TT**	Trinidad and Tobago
EE	Estonia	**MD**	Republic of Moldova	**UA**	Ukraine
ES	Spain	**MG**	Madagascar	**UG**	Uganda
FI	Finland	**ML**	Mali	**US**	United States of America
FR	France	**MN**	Mongolia	**UZ**	Uzbekistan
GA	Gabon	**MR**	Mauritania	**VN**	Viet Nam

ADAPTIVE CHANNEL ALLOCATION IN A FREQUENCY DIVISION MULTIPLEXED SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to cellular telecommunications systems and, more particularly, to a method and system of adaptive channel allocation in a frequency division multiplexed cellular system.

Description of the Prior Art

In a cellular telecommunications system the user of a mobile station communicates with the system through a radio interface while moving about the geographic coverage area of the system. The radio interface between the mobile station and system is implemented by providing base stations dispersed throughout the coverage area of the system, each capable of radio communication with the mobile stations operating within the system. In a typical cellular telecommunications system each base station of the system controls communications within a certain geographic coverage area termed a cell, and a mobile station which is located within a particular cell communicates with the base station controlling that cell. As a mobile station moves throughout the system control of the communication between the system and mobile station are transferred from cell to cell according to the movement of the mobile station throughout the system. Existing cellular telecommunications systems operate according to various air interface standards which assure the compatibility of equipment designed to operate in a particular system. Each standard provides specific details of the processes that take place between the mobile stations and base stations of the system in all modes of operation, including during idle states, during rescan of control channels, during registration, and

during connection to voice or traffic channels. Advances in cellular systems technology have been rapid in recent years. These advances in technology have been driven by increases in demand for the increasingly sophisticated services offered by cellular systems. As cellular systems technology and the total number of cellular systems has increased worldwide to meet this demand, there has also been an accompanying increase in the number of system standards according to which these cellular systems operate.

In cellular telecommunications systems, as in most radio systems, the frequency bandwidth available for use is a limited resource. Because of this, emphasis is often concentrated on making the most efficient use possible of the available frequency bandwidth when developing new cellular systems. Additionally, communications within cellular systems are often subject to certain types of RF signal distortion such as multipath propagation and co-channel interference. The development of new system standards has also emphasized the need to minimize the effect of these RF signal distortions on communications within the cells of a system.

Frequency division multiplexing (FDM) is a method of transmitting data that has application to cellular systems. Orthogonal frequency division multiplexing (OFDM) is a particular method of FDM that is particularly suited for cellular systems. An OFDM signal consists of a number of subcarriers multiplexed together, each subcarrier at a different frequency and each modulated by a signal which varies discretely rather than continuously. Because the level of the modulating signal varies discretely, the power spectrum of each subcarrier follows a $(\sin x/x)^2$ distribution. The spectral shape transmitted on each subcarrier is such that the spectra of the individual sub-channels are zero at the other subcarrier frequencies and interference does not occur between subcarriers. Generally, N serial data elements modulate

N subcarrier frequencies, which are then frequency division multiplexed. Each of the N serial data elements comprises a data block with a duration of T=1/fs, where fs is the bandwidth of the OFDM signal. The subcarriers of the OFDM system are separated in frequency by multiples of 1/T. Although the frequency spectrum of the subcarriers overlap, this frequency spacing makes the subcarriers orthogonal over one symbol interval so that the peak of power of each modulated carrier occurs at frequencies corresponding to nulls in the power spectrum of the other carriers. The overall spectrum of an OFDM signal is close to rectangular when a large number of OFDM carriers are contained in the OFDM signal.

During the time period, T, the OFDM signal may be represented by a block of N samples. The value of the N samples is as follows:

$$x(n) = \sum_{k=0}^{N-1} X(k)\, e^{2jnk/N}$$

The N values X(k) represent the respective data during period T, of the discretely-varying signals modulating the OFDM carriers $e^{2jnK/N}$. From the above, the OFDM signal corresponds to the inverse Discrete Fourier Transform of the set of data samples X(k). To convert a data stream into an OFDM signal, the data stream is split up into blocks of N samples X(k) and an inverse Discrete Fourier Transform is performed on each block. The string of blocks that appears at a particular sample position over time constitutes a discretely-varying signal that modulates a certain subcarrier at a frequency fn.

OFDM offers several advantages that are desirable in a cellular system. In OFDM the orthogonality of the subcarriers in the frequency spectrum allows the overall spectrum of an OFDM signal to be close to rectangular. This results in efficient use of the bandwidth available

to a system. OFDM also offers advantages in that interference caused by multipath propagation effects is reduced. Multipath propagation effects are caused by radio wave scattering from buildings and other structures in the path of the radio wave. Multipath propagation may result in frequency selective multipath fading. In an OFDM system the spectrum of each individual data element normally occupies only a small part of the available bandwidth. This has the effect of spreading out a multipath fade over many symbols. This effectively randomizes burst errors caused by the frequency selective multipath fading, so that instead of one or several symbols being completely destroyed, many symbols are only slightly distorted. Additionally, OFDM offers the advantage that the time period T may be chosen to be relatively large as compared with symbol delay time on the transmission channel. This has the effect of reducing intersymbol interference caused by receiving portions of different symbols at the same time.

The use of OFDM in cellular systems has been proposed by Cimini, "Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing", IEEE Trans. Commun., Vol. 33, No. 7, pp. 665-675 (July, 1985). A similar application of OFDM in a mobile system has also been proposed by Casa, "OFDM for Data Communication Over Mobile Radio FM-Channels-Part I: Analysis and Experimental Results", IEEE Trans. Commun., Vol. 39, No. 5, pp. 783-793 (May, 1991). In these OFDM cellular systems a set of subcarrier frequencies is assigned to each communications link created for transmission from a base station to a mobile station (downlink) and from a mobile station to a base station (uplink) operating within a cell. The set of subcarrier frequencies allocated to each communications link is chosen from all subcarrier frequencies available to the system. Within a cell the same subcarrier frequency cannot be assigned to more than one communications link.

Thus, co-channel interference between subcarriers within the same cell does not occur. However, it is possible in such an OFDM system that a communications link in a cell of the system is assigned a set of subcarriers frequencies that includes one or more subcarriers frequencies also assigned to a communications link set up in another cell within the system. Each of these commonly assigned subcarriers frequencies may be subject to co-channel interference caused by the use of the same subcarrier frequency in the other cells. In these OFDM systems no method or system exists for coordinating the assignment of subcarrier frequencies to communications links created within different cells. In such a system the co-channel interference in a communications link caused by a subcarrier used in a neighboring cell could be very large.

Methods of allocating channel frequencies among cells in non-OFDM systems have been developed that reduce or minimize co-channel interference. Adaptive Channel Allocation (ACA) is such a method. In ACA any channel frequency allocated to a cellular system may be used to set up a link in any cell of the system regardless of whether or not the frequency is used elsewhere in the system as long as certain interference criteria are met. The channel frequencies may also be freely reused throughout the system as long as the interference criteria are met.

In Adaptive Channel Allocation various measurements of signal quality and interference levels on dynamically allocated channel frequencies are performed within the coverage area of a cell to build a list of traffic or voice channels that may be assigned to communications links to be created within the cell. The base station controlling the cell and mobile stations within the cell's coverage area perform measurements on the set of channel frequencies that the system operator has allocated to be dynamically allocated for communications within the system. Generally, both uplink and downlink measurements

are performed. Based on these measurements, when a new link is to be created, a channel frequency is assigned to the link based on some rule. For example, in minimum interference ACA the system builds a table of channels from the least interfered (highest quality) to the most interfered (lowest quality) channels as measured within each cell. The system then selects a certain number of least interfered channel frequencies from that list to allocate to communication in that cell. Other criteria, such as certain required frequency separation between the channels chosen and avoiding certain combinations of channels whose frequencies create intermodulation are also considered. As an example of ACA, H. Eriksson, "Capacity Improvement by Adaptive Channel Allocation", IEEE Global Telecomm. Conf., pp. 1355-1359, Nov. 28-Dec. 1, 1988, illustrates the capacity gains associated with a cellular radio system where all of the channels are a common resource shared by all base stations. In the above-referenced report, the mobile measures the signal quality of the downlink, and channels are assigned on the basis of selecting the channel with the highest carrier to interference ratio (C/I level).

Existing ACA algorithms which have been created for non-OFDM cellular systems using one carrier frequency for each link cannot be effectively used in a cellular system using OFDM. One problem with the existing ACA techniques is that the number of subcarriers in an OFDM system is large compared to the number of carriers in the system that uses a single carrier for each communications link. This requires an extensive measurement effort that expends both time and system resources to obtain the uplink and downlink measurement results necessary for ACA. In addition, in order to transfer the results of the large number of downlink measurements made at a mobile station to the system for processing, use of a large amount of signaling resources is necessary.

It would provide an advantage then, to have a method and system of adaptive channel allocation for use in an OFDM system. The method and system should provide an allocation of subcarriers within an OFDM system that lessens co-channel interference between cells of the system. The method and system should also be designed to take into account the unique features of the OFDM system in order to utilize system resources effectively when allocating channels. The present invention provides such a method and system.

SUMMARY OF THE INVENTION

The present invention provides a method and system of adaptive channel allocation (ACA) in an orthogonal frequency division multiplexed (OFDM) system. The method and system provides an allocation of subcarriers to each link of the OFDM system that lessens co-channel interference between cells of the system.

The present invention also overcomes the difficulties and shortcomings presented with implementing conventional ACA methods and systems designed for use in a non-OFDM system into an OFDM system. Conventional ACA methods are designed to adaptively allocate RF channels to systems where one channel is used per link. As applied to an OFDM system, these conventional ACA methods would require that all OFDM subcarriers assigned to users to be adaptively allocated. Adaptively allocating all OFDM subcarriers in an OFDM system would require an overly large amount of measurement and signaling resources to transfer channel measurement information and the assignment information between receivers and transmitters of the system. By selectively choosing the subcarriers to be adaptively allocated, and setting criteria for allocation determination, the system and method of the present invention minimizes the use of measurement and signaling resources while still providing effective ACA.

In a first aspect of the invention, an initial subset of M subcarriers is chosen from a larger group of N subcarriers that are available for communications on each separate link of the OFDM system. The number M depends on the data rate of the particular link and may vary between the links of the system. The subset of M subcarriers is then used to carry communications on the link. As communications take place, the signal quality level (C/I) of the subcarriers within the subset of M subcarriers, and the interference level (I) of all N available subcarriers is periodically measured. These C/I and I measurement results are reported to the system. During communications on the link the system determines from the C/I and I measurements if a more preferred unused subcarrier which would give better signal reception on the link than a subcarrier of the set of M is available in the cell within which the link exists. If it is determined that a more preferred unused subcarrier exists, the system reconfigures the subset of M subcarriers to include the unused subcarrier.

In a second aspect of the invention, a mobile station as link receiver transmits only a limited set of measurement results to the system at certain select reporting intervals rather than all measurement results. The transmitted limited set of measurement results comprises a select number of the lowest C/I measurement results and a select number of the lowest I measurement results. The transmission of the limited set of results reduces the use of uplink system signaling resources.

In an alternative embodiment of the invention a mobile station as link receiver periodically measures the signal quality level (C/I) of the subcarriers within the subset of M subcarriers, and the interference level (I) of all N available subcarriers. The mobile station then determines candidate replacement subcarriers for the link based on the C/I and I measurements, and transmits a subcarrier request message to the system requesting that

the candidate subcarrier be assigned to replace a subcarrier of the link. The system responds to the subcarrier request message with a subcarrier accepted or subcarrier rejected message. If a subcarrier accepted message is received, the mobile station reconfigures the subset of M subcarriers to contain the candidate replacement subcarrier. If the subcarrier is rejected, the mobile station transmits a subcarrier request message requesting a new candidate subcarrier.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a cellular telecommunications network within which the present invention may be implemented;

FIG. 2A illustrates the allocation of subcarriers in accordance with the present invention in an orthogonal frequency division multiplexed system;

FIG. 3A is a block diagram of a system according to an embodiment of the present invention;

FIGS. 3B and 3C are block diagrams of a link transmitter and link receiver, respectively, according to an embodiment of the present invention;

FIGS. 4A and 4B are flow diagrams of process steps according to an embodiment of the present invention performed by a link receiver;

FIG. 5 is a flow diagram of process steps according to an embodiment of the present invention performed within a cellular telecommunications network;

FIGS. 6A and 6B are flow diagrams of process steps according to an alternative embodiment of the present invention performed by a link receiver; and

FIG. 7 is a flow diagram of process steps according to an alternative embodiment of the present invention performed within a cellular telecommunications system.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is illustrated a frequency division multiplexed (FDM) cellular telecommunications system of the type to which the present invention generally pertains. In FIG. 1, an arbitrary geographic area may be divided into a plurality of contiguous radio coverage areas, or cells C1-C10. While the system of FIG. 1 is illustratively shown to include only 10 cells, it should be clearly understood that in practice, the number of cells will be much larger.

Associated with and located within each of the cells C1-C10 is a base station designated as a corresponding one of a plurality of base stations B1-B10. Each of the base stations B1-B10 includes a transmitter, a receiver, and a base station controller as are well known in the art. In FIG. 1, the base stations B1-B10 are illustratively located at the center of each of the cells C1-C10, respectively, and are equipped with omni-directional antennas. However, in other configurations of the cellular radio system, the base stations B1-B10 may be located near the periphery, or otherwise away from the center of the cells C1-C10 and may illuminate the cells C1-C10 with radio signals either omni-directionally or directionally. Therefore, the representation of the cellular radio system of FIG. 1 is for purposes of illustration only and is not intended as a limitation on the possible implementations of the cellular telecommunications system within which the present invention is implemented.

With continuing reference to FIG. 1, a plurality of mobile stations M1-M10 may be found within the cells C1-C10. Again, only 10 mobile stations are shown in FIG. 1 but it should be understood that the actual number of mobile stations will be much larger in practice and will invariably greatly exceed the number of base stations. Moreover, while none of the mobile stations M1-M10 may be found in some of the cells C1-C10, the presence or absence of the mobile stations M1-M10 in any particular one of the

cells C1-C10 should be understood to depend in practice on the individual desires of the users of mobile stations M1-M10 who may roam from one location in the cell to another or from one cell to an adjacent cell or neighboring cell, and even from one cellular radio system served by a particular MSC to another such system.

Each of the mobile stations M1-M10 is capable of initiating or receiving a telephone call through one or more of the base stations B1-B10 and a mobile station switching center MSC. A mobile station switching center MSC is connected by communication links, e.g., cables, to each of the illustrative base stations B1-B10 and to the fixed public switched telephone network PSTN, not shown, or a similar fixed network which may include an integrated system digital network (ISDN) facility. The relevant connections between the mobile station switching center MSC and the base stations B1-B10, or between the mobile station switching center MSC and the PSTN or ISDN, are not completely shown in FIG. 1 but are well known to those of ordinary skill in the art. Similarly, it is also known to include more than one mobile station switching center in a cellular radio system and to connect each additional mobile station switching center to a different group of base stations and to other mobile station switching center via cable or radio links.

Each MSC may control in a system the administration of communication between each of the base stations B1-B10 and the mobile stations M1-M10 in communication with it. As a mobile station roams about the system, the mobile station registers its location with the system through the base station that controls the area in which the mobile station is located. When the mobile station telecommunications system receives a call addressed to a particular mobile station, a paging message addressed to that mobile station is broadcast on control channels of the base stations which control the area in which the mobile station is believed to be located. Upon receiving

the paging message addressed to it, the mobile station scans system access channels and sends a page response to the base station from which it received the strongest access channel signal. The process is then initiated to create the call connection. The MSC controls the paging of a mobile station believed to be in the geographic area served by its base stations B1-B10 in response to the receipt of a call for that mobile station, the assignment of radio channels to a mobile station by a base station upon receipt of a page response from the mobile station, as well as the handoff communications with a mobile station from one base station to another in response to the mobile station traveling through the system, from cell to cell, while communication is in progress.

Each of the cells C1-C10 is allocated a plurality of FDM subcarrier frequencies and at least one dedicated control channel. The control channel is used to control or supervise the operation of mobile stations by means of information transmitted to and received from those units. Such information may include incoming call signals, outgoing call signals, page signals, page response signals, location registration signals and voice and traffic subcarrier assignments.

The present invention involves implementation of a method and system of adaptive channel allocation (ACA) into an FDM cellular system as shown in FIG. 1. In an exemplary embodiment of the invention, ACA is implemented into an OFDM system operating with a total system bandwidth of 5MHz and a subcarrier spacing of 5KHz. The total number of subcarriers available for this system is approximately 5MHz/5KHz = 1000. The subcarriers are modulated onto a system RF carrier with a frequency of 2GHz for transmission over the system RF channel and the frequency spectra of the transmitted signal is centered around the RF carrier. All subcarriers are available for use in each cell but a subcarrier may not be used simultaneously on more than one link in a cell. Frequency

division duplex (FDD) is used for separation of the uplink and downlink subcarriers frequencies. The system includes a dedicated control channel (DCCH) that is both an uplink and downlink channel for transmitting control information for handovers, long term channel allocation information, long term power control information and measurement messages and measurement results. The system also includes a physical control channel (PCCH) that is both an uplink and downlink channel for transmitting short term channel allocation information, short term power control information, measurement messages and measurement results.

In the ACA of the invention, for each up/down link between a mobile station and base station, the system chooses a subset of a number (M) of subcarriers from a set of a number (N) of subcarriers. The set of N subcarriers is the set of subcarriers available within the system for each link, where N>M. The set of N subcarriers does not change during a communication. The set of N subcarriers may include all subcarriers of the system. Alternatively, the set of N subcarriers may be a set less in number than the total number of subcarriers available but greater in number than the number of carriers in the subset of M subcarriers.

Referring now to FIG. 2 therein is illustrated the allocation of subcarriers in accordance with the present invention in an OFDM system. Base station 200 communicates with mobile station 202 over downlink 206 and uplink 208. Base station 200 also communicates with mobile station 204 over downlink 210 and uplink 212. Transmissions on links 206, 208, 210 and 212 are made over the system RF channel. Voice and data to be transmitted on each link are modulated onto a number (M) subcarriers. The M subcarriers are then modulated onto the system RF carrier for transmission over the system RF channel. Each link 206, 208, 210 and 212, within the cell uses a separate subset of M subcarriers. The subcarriers can only be used once within a cell.

Referring now to FIG. 3A, therein is shown a block diagram of a system according to the present invention. The system consists of a link transmitter 300, link receiver 330, ACA processing portion 360 and RF channel 380. The receiver 330 and transmitter 300 of a particular link are located at opposite ends of the link. In the downlink the receiver 330 is located in the mobile station and the transmitter 300 is located in the base station. In the uplink the receiver 330 is located in the base station and the transmitter 300 is located in the mobile station. RF channel has a set of N available subcarriers. The link receiver 330 and link transmitter communicate over RF channel 380 using a subset of M of the available subcarriers.

Referring now to FIGS. 3B and FIG. 3C, therein are shown functional block diagrams of transmitter 300 and receiver 330, respectively, of FIG. 3A. The functional features that are shown in FIG. 3B and FIG. 3C are common to both the base and mobile station receivers and transmitters.

Transmitter 300 includes a serial to parallel converter 302, mapping circuitry (MAP) 304, inverse fast fourier transform (IFFT) circuitry 306, a frequency multiplexer (MuX) 308, and modulator 310. In transmitter operation, serial to parallel converter 302 converts a serial digital data stream 312 into blocks of M symbols 314 where M is determined by the symbol size and data rate of the system. The M symbols are then input to the MAP circuitry 304, where each of the M symbols is mapped onto a subcarrier input of the IFFT circuitry 306. An inverse fast fourier transform (IFFT) is then performed on the blocks of data input to the IFFT circuitry 306. The signals 318 generated at the N outputs of the IFFT circuitry 306 are then multiplexed in MuX 308 to create a signal 320 containing M multiplexed subcarriers, each of which carries the data contained in one symbol of the M symbols 314. The signal 320 is then modulated onto the

system RF carrier 324 at modulator 310 and transmitted as an OFDM signal over the system RF channel 322.

Receiver 330 includes demodulator 332, frequency demultiplexer (DEMUX) 334, fast fourier transform (FFT) circuitry 336, de-mapping circuitry (DEMAP) 338, a parallel to serial converter 340, interference measuring means 344, signal quality measurement means 342 and processor 346. In receiver operation, the system RF carrier is received on the system RF channel 322 and then demodulated at demodulator 332, and demultiplexed at DEMUX 334 to obtain N samples 348 of the signal containing, the M multiplexed subcarriers. A fast fourier transform (FFT) is then performed by FFT circuitry 336 with the N samples 348 as inputs to generate data signals 350 containing any modulating data that was transmitted on each subcarrier. The N subcarriers demodulated and subjected to the FFT are determined by parameters input to DEMUX 334 and FFT circuitry 336 from processor 346. Interference measurement means 344 measures the interference (I) level on each of the data signals 350 recovered from each of the N samples 348. The N received data signals 350 are then input to the de-mapping block 338 where the M data signals 352 received on the M subcarrier frequencies currently assigned to link communications are de-mapped from the N data signals 350. The de-maping is done according to parameters input to DEMAP block 338 from processor 346. The M de-mapped data signals 352 are then input to the parallel to serial converter 340 and converted into serial received data 354. Signal quality (C/I) is measured at the output of the de-mapping block 338 for each of the M de-mapped data signals 352 received on the M subcarrier frequencies currently assigned to the link on which receiver 330 is receiving.

The adaptive channel allocation for each link is implemented by ACA processing portion 360 of FIG. 3A which operates on results of measurements performed in the link receiver. In the embodiment shown, processor 346 receives

interference measurements from interference measurement means 344 and signal quality measurement results from signal quality measurement means 342. The processor 346 operates on the measurement results to generate data for input to ACA processing portion 360 of the system. The data generated by processor 346 will then be transferred to ACA processing portion 360 over interface 362. In the embodiment shown, ACA processing portion 360 is located within the MSC. ACA processing portion 360 may be alternatively located within the base stations of the system. It is also conceivable the functions performed by the ACA processing portion be distributed among the mobile station, base station and MSC. Methods of configuring memories to store the necessary data, and methods of configuring microprocessors and software to perform these types of functions are well known to those skilled in the art.

When a mobile station functions as link receiver, the processor 346 transfers the ACA data to the mobile station transmitter for transmission to the system over interface 362 which comprises the uplink on the appropriate control channel. In a base station as link receiver, the processor 346 transfers the ACA data to the MSC over interface 362 which comprises landline or other connections. ACA processing portion 360 operates on the data and then returns appropriate subcarrier assignment commands to link receiver 330 over interface 364 which comprises landline or other connections when the base station is the link receiver, or the down link on the appropriate control channel when the mobile station is the link receiver. Processor 346 of link receiver 330 receives the commands and then generates the correct input parameters for the receiver so that the correct subcarriers for the link are received. ACA processing portion 360 also sends commands to MAP circuitry 304 associated with link transmitter 300 over interface 366. MAP circuitry 304 then maps the M symbols to the appropriate outputs of MAP circuitry 304

so that the correct subset of M subcarriers is transmitted on.

The necessary data transfer between the mobile stations, base stations and MSCs of the system may be accomplished by known methods. In the described embodiment the DCCH and PCCH channels may be used on both the uplink and downlink to transfer measurement results or subcarrier assignment messages between a mobile station and the system. The use of control channels to carry such information is known to those skilled in the art.

Referring now to FIG. 4A, therein is shown a flow diagram illustrating the steps performed by the link receiver 330 during the ACA process. The steps performed by a mobile station receiving on a downlink and the steps performed by a base station receiving on an uplink are essentially identical and FIG. 4A can be used to describe the steps performed by the link receiver 330 in both cases. The differences between the process steps performed in the mobile station and base station involve step 428 of FIG. 4A. FIG. 4B is a flow diagram that illustrates additional steps performed by the mobile station during step 428 of the ACA measurement process. These extra steps will be described with reference to FIG. 4B as the process of FIG. 4A is described.

The ACA process begins when it is necessary for the system to create a communications link between a mobile station base station pair on either the uplink or the downlink. Referring again to FIG. 4A, at step 402 the link receiver receives from the system a measurement order message to measure interference (I) on each of a group of N subcarriers available for the link. The N subcarriers may be all subcarriers available within the system or a smaller group of subcarriers chosen from all subcarriers available within the system. Next, at step 404 the I measurements are performed. Then, from step 404 the process moves to step 406 where the I measurement results are sent to the system. When a mobile station is the link

receiver, the I measurement results are transmitted over the DCCH or PCCH channel to the base station and then transferred to the MSC. When a base station is the link receiver, the I measurement results are transferred to the MSC via the appropriate overland means. After transmitting the I measurement results the process moves to step 408 where the link receiver waits for a response from the system. The process steps that take place when the link receiver is in the wait state at step 408 will now be described with reference to FIG. 5.

Referring now to FIG. 5, therein are shown the process steps performed within the ACA processing portion of system during the ACA process. At step 502 the results of the I measurement performed on the N subcarriers at the link receiver are received by the ACA processor. Next, at step 504 the ACA processor determines the M least interfered unused subcarriers from the results of the I measurements made on the N subcarriers. From step 504 the process then moves to step 506 where a subcarrier assignment message assigning the subset of the least interfered M subcarriers to the link is sent to both the link receiver and the link transmitter. The ACA processor now moves to step 508 and waits for further input from the link receiver. The process flow now returns to step 408 FIG. 4A. Alternative methods of determining the M subcarriers for the subcarrier assignment message may be used in place of step 506. For example, the subcarriers could be assigned on the basis of how their use effects transmissions in neighboring cells. If one of the least interfered M subcarriers was used in a neighbor cell, the subcarrier would not be used. In this case the M subcarriers may not be the least interfered M subcarriers.

Referring again to FIG. 4A, the link receiver which has been in the wait state at 408 now moves to step 410 and receives the channel assignment message assigning the subset of M subcarriers to the link. Next, the process moves to step 412 as the link receiver begins receiving

on the link using the assigned subset of M subcarriers. From step 412 the process now moves to step 414 and waits for further input. At step 416 an input is received. The link receiver may receive three types of inputs while receiving using the assigned subset of M subcarriers. At decision step 418 the link receiver determines if a call end signal has been received. If a call end signal has been received the process ends. The call end signal may have been transmitted by the system to the link receiver or initiated at the link receiver itself. A call end signal indicates to the process that communications on the link have terminated. If a call end has not been received, the process moves to step 420 and the link receiver determines whether a measurement timer message has been received. The measurement timer is contained in the processor associated with the link receiver. The measurement timer generates a measurement message at periodic intervals informing the link receiver to make measurements. Each measurement timer signal defines a measurement interval. If a measurement timer message has been received the process moves to step 424. At step 424 the link receiver measures I on the set of N subcarriers. The I measurements may be averaged with the results of a certain number of previous I measurements for each subcarrier to obtain accuracy. The first time through step 424 the measurements are averaged with the results obtained in step 404. On subsequent passes through step 424 the measurement results are averaged with the last n previous measurements, where n is a value allowing an accurate following of a subcarrier's interference level within the system. From step 424 the process moves to step 426 and the link receiver measures C/I on each of the subset of M carriers. The C/I measurements are also averaged with the last n previous C/I measurements. Then, at step 428 the link receiver sends the I and C/I measurement results to the ACA processing portion of the system. Depending on whether the link receiver is the

base station or mobile station, step 428 may be performed in differing ways. If the link receiver is a base station the averaged measurement results may be sent directly to the ACA processor. If the link receiver is a mobile station in a downlink the substeps shown in FIG. 4B may be used to reduce signaling traffic as the results are transmitted to the system over the uplink via the base station.

Referring now to FIG. 4B, therein is shown a flow diagram illustrating process substeps performed by a mobile station performing step 428 of FIG. 4A. Signaling traffic on the uplink is reduced by transmitting differing sets of measurement results to the system over differing time intervals. Over long reporting intervals all I measurement and C/I measurement results are transmitted to the system. Over shorter reporting intervals a reduced set of each of the I measurement and C/I measurement results are transmitted. The long and short intervals may be defined so that a long interval occurs every nth short interval or every nth measurement period, where n is a number such as, for example, 25. At step 428a the mobile station determines whether the measurement period involves a short time interval for reporting measurement results. If it is determined that the measurement period involves a short time interval for reporting measurement results the process moves to step 428b, where the mobile station transmits the C/I measurements for the Y worst quality subcarriers of the subset of M subcarriers, where $Y<M$, and the I measurements for the Z least interfered of the N subcarriers to the system, where $Z<N$. The values of Y and Z are chosen to allow adequate information for effective ACA while minimizing signaling traffic. Y may be set to 1 and Z may be set to a number calculated to contain on average the I measurement results of at least one subcarrier not used within the same cell. The process then moves to step 414 where the mobile station waits for further input. However, if, at step 428a, it is

determined that the measurement period does not involve a short time interval for reporting measurement results the process moves to step 428c. At step 428c the mobile station transmits the C/I measurements for the whole subset of M subcarriers and the I measurements for all N subcarriers to the system. The process then moves to step 414 where the mobile station waits for further input. The process flow now moves to FIG. 5 as the ACA processor receives the measurement results from the link receiver.

Referring again to FIG. 5, the ACA processor which has been in the wait state at step 508, receives an input from the link receiver at step 510. The ACA processor may receive measurement results or a call end signal at step 510. When an input is received the process moves to step 512 where it is determined what type of input was received. If a call end signal is received the process ends. In this example the received message is measurement results so the process moves to step 514. At step 514 the ACA processor determines the subcarrier of the subset of M used subcarriers with the lowest C/I measurement value. Next, at step 516 it is determined if the C/I of the lowest C/I measurement value of the subset of M subcarriers is below the ACA C/I trigger threshold. If, at step 516, it is determined that the lowest C/I measurement value is not below the ACA C/I trigger threshold the process flow will return to step 508 where the ACA processor will wait for further input. If, however, at step 516 it is determined that the lowest C/I measurement value is below the ACA C/I trigger threshold the process flow will instead move to step 518. At step 518 the ACA processor determines whether an unused subcarrier of the set of N subcarriers exists which has an I measurement value less than the I measurement value of the subcarrier of the subset of M with the lowest C/I measurement value. If at step 518 it is determined that no unused subcarrier exists with a lower I measurement value, the process flow will return to step 508 where the

ACA processor will wait for further input. If, however, at step 518 an unused subcarrier exists with a lower I measurement value, a more preferred subcarrier exists and, the process moves to step 520. At step 520 the ACA processor inserts the least interfered unused subcarrier into the subset of M subcarriers and removes the subcarrier of the subset of M with the lowest C/I measurement value from the subset. To avoid hysterisis effects the change of subcarriers may be performed after calculating a C/I for the least interfered unused subcarrier during step 518 and determining that the calculated C/I is a minimum amount above the C/I of the subcarrier to be removed. If the C/I for the least interfered unused subcarrier is not a minimum amount above the C/I of the subcarrier to be removed the unused subcarrier can be considered not acceptable as a replacement. From step 520 the process moves to step 522 where the system sends a reconfigure subset message to the link receiver instructing the link receiver to reconfigure the subset of M subcarriers assigned to the link to conform to the changes made by the processor. Then the ACA processor moves to step 508 and waits for further input from the link receiver. The procedure given by steps 514-520 could alternately be performed by determining a plurality of less interfered unused subcariers and exchanging these with a plurality of used subcarriers having an interference level below the C/I threshold. The subset could also be reconfigured according to other criteria. For example, the subset of M could be reconfigured on the basis of the effect of using the subset, in the cell of the link, on communications occurring in neighbor cells. If some of the M subscarriers used in the cell were also used in neighbor cells, these could be replaced with subcarriers unused in the cell and also not used in neighbor cells. Reconfiguration could take place even if the used subcarriers were not below a C/I threshold or even if the

unused subcarrier had an interference level greater than the replaced subcarriers.

The process continues as long as a call is ongoing and communications on the link continue. The link receiver will next move from the wait state at step 408 upon receiving an input and the process steps shown in FIGS. 4A, 4B and 5 will be repeated until the call ends and a call end signal is received by the link transmitter, link receiver and ACA processing portion of the system.

In an alternative embodiment of the invention, a mobile station as link receiver transmits request messages requesting a certain subset of M subcarriers, or requesting replacements for the M subcarriers, to be used on the link. Signal measurement results need not be transmitted from the mobile station to the system. The system in turn transmits subset accepted or subcarrier accepted messages to the mobile station. The downlink ACA processing mainly takes place in the processor 346 of the receiver in the mobile station. In this alternative embodiment steps 504, 514, 516, 518 and 520 shown in FIG. 5, which are performed by the system in the first embodiment, would be performed by processor 346 in the mobile station. The base station ACA process flow for uplink measurements remains as illustrated in FIGS. 4A, 4B and 5.

Referring now to FIG. 6A, therein is shown a flow diagram illustrating the steps performed by a mobile station as the link receiver during the ACA process of the alternative embodiment of the invention. The ACA process begins when the mobile station receives a measurement order message at Step 602. Next, at Step 604 the interference (I) on each of the group of N subcarriers available for the link is measured at the mobile station. Next, the process moves to Step 606 where the M least interfered subcarriers are determined. From Step 606 the process moves to Step 608 and a subset request message is sent to the system by the mobile station. The subset

request message indicates to the system that the mobile station requests the use of each subcarrier in the requested subset. The process now moves to Step 610 and the mobile station waits for an answer from the system. The process steps that take place when the process is in the wait state at Step 610 will now be described with reference to FIG. 7.

Referring now to FIG. 7, therein are shown process steps performed within the ACA processing portion of the system according to the alternative embodiment of the invention when the mobile station is involved in the ACA process. At Step 702 the ACA processing portion receives the subset request message. Next, at Step 704 the system determines if the mobile is allowed to use all of the M subcarriers in the requested subset. Certain subcarriers may not be available for use in the cell, for example, if they are being used by another mobile station or, if they have been reserved within the system for special uses. The availability of the M subcarrier may also be determined as to how their use effects transmissions in neighboring cells. The ACA is designed to allow flexibility to the system operators in making these decisions. If it is determined that the mobile station is allowed to use all M subcarriers in the requested subset, the system will transmit a subset accepted message to the link receiver. If however, at Step 704, it is determined that subcarriers of the suggested subset cannot be used by the mobile station, the process moves to Step 720 and the system transmits a subcarrier rejected message rejecting the unavailable subcarriers as part of the subset of M subcarriers. The process flow now moves to Step 722 as the process waits for a reply from the mobile station.

Referring now to FIG. 6A, at Step 612 the mobile station receives a subset accepted message or subcarrier rejection message transmitted from the system. If a subset acceptance message is received, the process moves

to Step 620 where the link receiver begins receiving using the assigned subset. If however, at Step 614, it is determined that a subcarrier rejected message(s) has been received, the process moves to Step 616. At Step 616, the link receiver determines the next candidate(s) to replace the rejected requested subcarrier(s). These candidates would be the next least interfered subcarriers of the set of N available subcarriers that are not in the suggested set of M.

From Step 616 the process then moves to Step 618 where a subcarrier request message requesting the next candidate subcarrier(s) is transmitted to the system. The process then moves to Step 610 as the link receiver waits for an answer. The process will continue through the loops formed by the Steps 610, 612, 614, 616, 618, and, 706 and 708, until the complete subset of M subcarriers is accepted. Then the process moves to Step 620 where the mobile station begins receiving on the link using the accepted subset. The process now moves to the wait state of Step 622. When in the wait state of Step 622 the process may receive either a call end or measurement timer message. The call end and measurement timer messages are equivalent to the call end and measurement messages described above for the previous embodiment of the invention. The link receiver receives the call end or measurement timer message at Step 624 and moves to Step 626 where it is determined if a call end was received. If a call end is received the process ends. If, however, a measurement timer message was received, the process moves to Step 628. At Step 628 the mobile station measures I on all N available subcarriers and averages the results for each subcarrier. Next, at Step 630, the link receiver measures C/I on the subset of M subcarriers and averages the results for each subcarrier. The process now moves to Step 632 of FIG. 6B.

At Step 632 the link receiver determines the subcarrier of the subset of M with the lowest C/I. Next,

at Step 634 it is determined if the lowest C/I is below a threshold. If it is not below the threshold, the process returns to Step 622 where the link receiver waits for another call end or measurement timer message. If, however, it is determined that the lowest C/I is below the threshold C/I, the process moves to Step 636. At Step 636 it is determined if a less interfered subcarrier of the set of N not in the subset of M exists. If a less interfered subcarrier does not exist the process returns to Step 622. If, however, a less interfered subcarrier does exist, a more preferred subcarrier exists and the process moves to Step 638. At Step 638 the mobile station transmits a subcarrier request message to the system requesting the least interfered subcarrier not in the subset of M subcarriers as a replacement for the subcarrier with the lowest C/I. The process within the mobile station now moves to the wait state of Step 640 and the process flow moves to Step 708 of FIG. 7. The ACA processing portion of the system receives the requested subcarrier message at Step 710. The procedure outline in steps 632-638 could alternately be performed by determining a plurality of used subcarriers with the lowest C/Is of the subset and then determing a plurality of less interfered unused subcarriers as requested replacements. After receiving the subcarrier requested message it is determined, at step 716, if the requested subcarrier is used within the cell on a link with another mobile station. If the requested subcarrier is used within the cell the system moves to Step 718 and transmits a requested subcarrier rejected message to the mobile station and the process returns to Step 708. If, however, the suggested replacement is unused within the cell, the system transmits a requested subcarrier accepted message to the mobile station and the process returns to Step 708. As an alternative to determining if the requested subcarrier is used with the cell, other criteria may also be used to determine availability. For example, if the

requested subcarrier is used in a neighbor cell the system could reject the subcarrier request. The process then moves from the wait state of Step 640 to Step 642 as the mobile station receives the acceptance or rejection message. Next, at Step 644, it is determined if the requested subcarrier was accepted. If the requested subcarrier was accepted the process moves to Step 646 and the mobile station reconfigures the subset of M subcarriers on which the mobile station is receiving to include the requested subcarrier and deletes the subcarrier with the lowest C/I. Then, the process moves to the wait state of Step 622. If, however, the requested subcarrier is not accepted the process moves to Step 648. At Step 648 the mobile station determines if a new candidate subcarrier less interfered than the subcarrier of M subcarriers with the lowest C/I, that has not been already rejected as a requested subcarrier within this measurement interval, exists. If a new candidate subcarrier does not exist the process moves back to the wait state of Step 622. If, however, a new candidate subcarrier does exist, the process moves to Step 638 where the mobile station transmits a subcarrier request message to the system. The message requests the new candidate subcarrier found at Step 648 as the new replacement subcarrier. The process then moves to Step 640 and waits for an answer from the system. The process will continue through the loops formed by Steps 642, 644, 648, 650, and, 638 and 710, 712, 714, and 716 or 718, until a requested subcarrier is accepted or no new candidate exist. The process then moves to the wait state of Step 622. The ACA process will continue throughout the call and be invoked each time a measurement timer message is received. When the call ends, the process will end through Steps 624 and 626.

As can be seen from the above description, the invention provides a method and system of adaptive channel allocation for an OFDM system. Use of the invention will

enhance the performance of OFDM systems into which it is implemented. The adaptive channel allocation is designed to minimize the signaling resources necessary to carry measurement results on the system uplinks will still provide the benefits of adaptive channel allocation. The result is a system with better spectral efficiency, less dropped calls and better quality communications for each link.

It is believed that the operation and construction of the present invention will be apparent from the foregoing description and, while the invention shown and described herein has been characterized as particular embodiments, changes and modifications may be made therein without departing from the spirit and scope of the invention as defined in the following claims.

WHAT IS CLAIMED IS:

1. In a telecommunications system in which communications from a link transmitter to a link receiver are transmitted over a subset of a set of a plurality of subcarriers available to a link, a method of allocating subcarriers for communications on a link, said method comprising the steps of:

allocating a plurality of subcarriers from said set to provide said subset;

measuring a received signal on each subcarrier of said set;

determining if at least one unused subcarrier exists in said set that is more preferred for use on said link than a subcarrier of said subset; and

reconfiguring said subset in response to an affirmative determination.

2. The method of claim 1 in which said step of allocating comprises the steps of:

measuring an interference level (I) on each subcarrier of said set; and

determining said subset, said subset comprising a plurality of least interfered unused subcarriers of said set.

3. The method of claim 2 in which said step of measuring an interference level (I) further comprises the step of:

transmitting a plurality of results of said interference level (I) measurements from said link receiver to said system, wherein the number of said plurality of results transmitted is less than the number of subcarriers in said set.

4. The method of claim 1 in which said step of measuring comprises the steps of:

measuring the interference level (I) on each subcarrier of said set.

5. The method of claim 1 in which said step of measuring comprises the steps of:

measuring the signal quality (C/I) on each subcarrier of said subset.

6. The method of claim 1 in which said step of measuring comprises the steps of:

measuring the interference level (I) on each subcarrier of said set; and

measuring the signal quality level (C/I) on each subcarrier of said subset; and,

said step of determining comprises the steps of:

determining a subcarrier of said subset with a lowest signal quality level (C/I); and

determining if an unused subcarrier of said set exists that has an interference level (I) lower than the interference level (I) of said subcarrier of said subset with said lowest signal quality level (C/I).

7. The method of claim 6 in which said step of reconfiguring comprises the steps of:

removing said subcarrier with said lowest signal quality (C/I) from said subset in response to an affirmative determination; and

inserting said unused subcarrier into said subset.

8. The method of claim 6 in which said step of measuring the interference level (I) further comprises the steps of:

transmitting a plurality of results of said interference level (I) measurements from said link

receiver to said system, wherein the number of said results transmitted is less than the number of subcarriers in said set; and,

said step of measuring the signal quality (C/I) further comprises the steps of:

transmitting a plurality of results of said signal quality (C/I) measurements from said link receiver to said system, wherein the number of said results transmitted is less than the number of subcarriers in said subset.

9. The method of claim 1 in which said step of allocating comprises the steps of:

measuring an interference level (I) on each subcarrier of said set;

determining a candidate subset, said candidate subset comprising a plurality of least interfered subcarriers of said set;

transmitting a subset request message from said link receiver to said system;

receiving an answer message from said system at said link receiver; and

determining whether said candidate subset is accepted for said link from said answer message.

10. The method of claim 9 in which said step of receiving an answer message comprises receiving a subset accepted message.

11. The method of claim 9 in which said step of receiving an answer message comprises receiving one or more subcarrier rejected messages, and said step of determining whether said candidate subset is accepted further comprises the steps of:

determining one or more next candidate subcarriers for said subset;

transmitting one or more subcarrier requested messages from said link receiver to said system; and

repeating said steps of determining one or more next candidate subcarriers and transmitting one or more subcarrier requested messages to said system until a complete subset is accepted.

12. The method of claim 1 in which said step of determining if an unused subcarrier exists comprises the steps of:

determining if a candidate subcarrier of said set exists that is more preferred for use on said link than a subcarrier of said subset;

transmitting a subcarrier request message from said link receiver to said system;

receiving an answer from said system at said link receiver;

determining from said answer if said candidate subcarrier is unused; and

repeating, in response to a negative determination, the steps of determining if a subcarrier of said set exists that is more preferred, transmitting a subcarrier request, receiving an answer, and determining from said answer, each time with a different candidate subcarrier, until said step of determining from said answer results in an affirmative determination.

13. The method of claim 12 in which said step of measuring a received signal on each subcarrier of said subset comprises the steps of:

measuring the interference level (I) on each subcarrier of said set; and

measuring the signal quality level (C/I) on each subcarrier of said subset; and

said step of determining if a candidate subcarrier exists in said set that is more preferred

for use on said link than a subcarrier of said subset comprises the steps of:

determining a subcarrier of said subset with a lowest signal quality level (C/I); and

determining a candidate subcarrier of said set that has an interference level (I) lower than the interference level (I) of said subcarrier of said subset with said lowest signal quality level (C/I).

14. In a telecommunications network in which communications from a link transmitter to a link receiver are transmitted over a subset of a set of a plurality of subscribers available to a link, a system for allocating subcarriers for communications on a link, said system comprising:

means for allocating a plurality of subcarriers from said set to provide said subset;

means for measuring a received signal on each subcarrier of said subset;

means for determining if at least one unused subcarrier exists in said set that is more preferred for use on said link than a subcarrier of said subset; and

means for reconfiguring said subset in response to an affirmative determination.

15. The system of claim 14 in which said means for allocating comprises:

means for measuring an interference level (I) on each subcarrier of said set; and

means for determining a subset, said subset comprising a plurality of least interfered subcarriers of said set.

16. The system of claim 15 in which said means for measuring an interference level (I) further comprises:

means for transmitting a plurality of results of said interference level (I) measurements from said link receiver to said system, wherein the number of said plurality of results transmitted is less than the number of subcarriers in said set.

17. The system of claim 14 in which said means for measuring comprises:

means for measuring the interference level (I) on each of subcarriers of said set.

18. The system of claim 14 in which said means for measuring comprises:

means for measuring the signal quality (C/I) on each subcarriers of said subset.

19. The system of claim 14 in which said means for measuring comprises:

means for measuring the interference level (I) on each subcarrier of said set; and

means for measuring the signal quality level (C/I) on each subcarrier of said subset; and,

said means for determining comprises:

means for determining a subcarrier of said subset with a lowest signal quality level (C/I); and

means for determining if an unused subcarrier of said set exists that has an interference level (I) lower than the interference level (I) of said subcarrier of said subset with said lowest signal quality level (C/I).

20. The system of claim 19 in which said means for reconfiguring comprises:

means for removing said subcarrier with said lowest signal quality (C/I) from said subset in response to an affirmative determination; and

means for inserting said unused subcarrier into said subset.

21. The system of claim 19 in which said means for measuring the interference level (I) further comprises:

means for transmitting a plurality of results of said interference level (I) measurements from said link receiver to said system, wherein the number of said results transmitted is less than the number of subcarriers in said set; and,

said means for measuring the signal quality (C/I) further comprises:

means for transmitting a plurality of results of said signal quality (C/I) measurements from said link receiver to said system, wherein the number of said results transmitted is less than the number of subcarriers in said subset.

22. The method of claim 14 in which said means for allocating comprises:

means for measuring an interference level (I) on each subcarrier of said set;

means for determining a candidate subset, said candidate subset comprising a plurality of least interfered subcarriers of said set;

means for transmitting a subset request message from said link receiver to said system;

means for receiving an answer message from said system at said link receiver; and

means for determining whether said candidate subset is accepted for said link from said answer message.

23. The system of claim 22 in which said means for receiving an answer message comprises means for receiving a subset accepted message.

24. The system of claim 22 in which the means for receiving an answer message comprises means for receiving one or more subcarrier rejected messages, and said means for determining whether said candidate subset is accepted further comprises:

means for determining one or more next candidate subcarriers for said subset;

means for transmitting one or more subcarrier requested messages from said link receiver to said system; and

means for repeating said steps of determining one or more next candidate subcarriers and transmitting one or more subcarrier requested messages to said system until a complete subset is accepted.

25. The method of claim 14 in which said means for determining if an unused subcarrier exists comprises:

means for determining if a candidate subcarrier of said set that is more preferred for use on said link than a subcarrier of said subset;

means for transmitting a subcarrier request message from said link receiver to said system;

means for receiving an answer from said system at said link receiver; and

means for determining from said answer if said candidate subcarrier is unused.

26. The method of claim 25 in which said means for measuring a received signal on each subcarrier of said subset comprises:

means for measuring the interference level (I) on each subcarrier of said set; and

means for measuring the signal quality level (C/I) on each subcarrier of said subset; and

said means for determining if a candidate subcarrier exists in said set that is more preferred for use on said link than a subcarrier of said subset comprises:

means for determining a subcarrier of said subset with a lowest signal quality level (C/I); and

means for determining a candidate subcarrier of said set that has an interference level (I) lower than the interference level (I) of said subcarrier of said subset with said lowest signal quality level (C/I).

FIG. 1

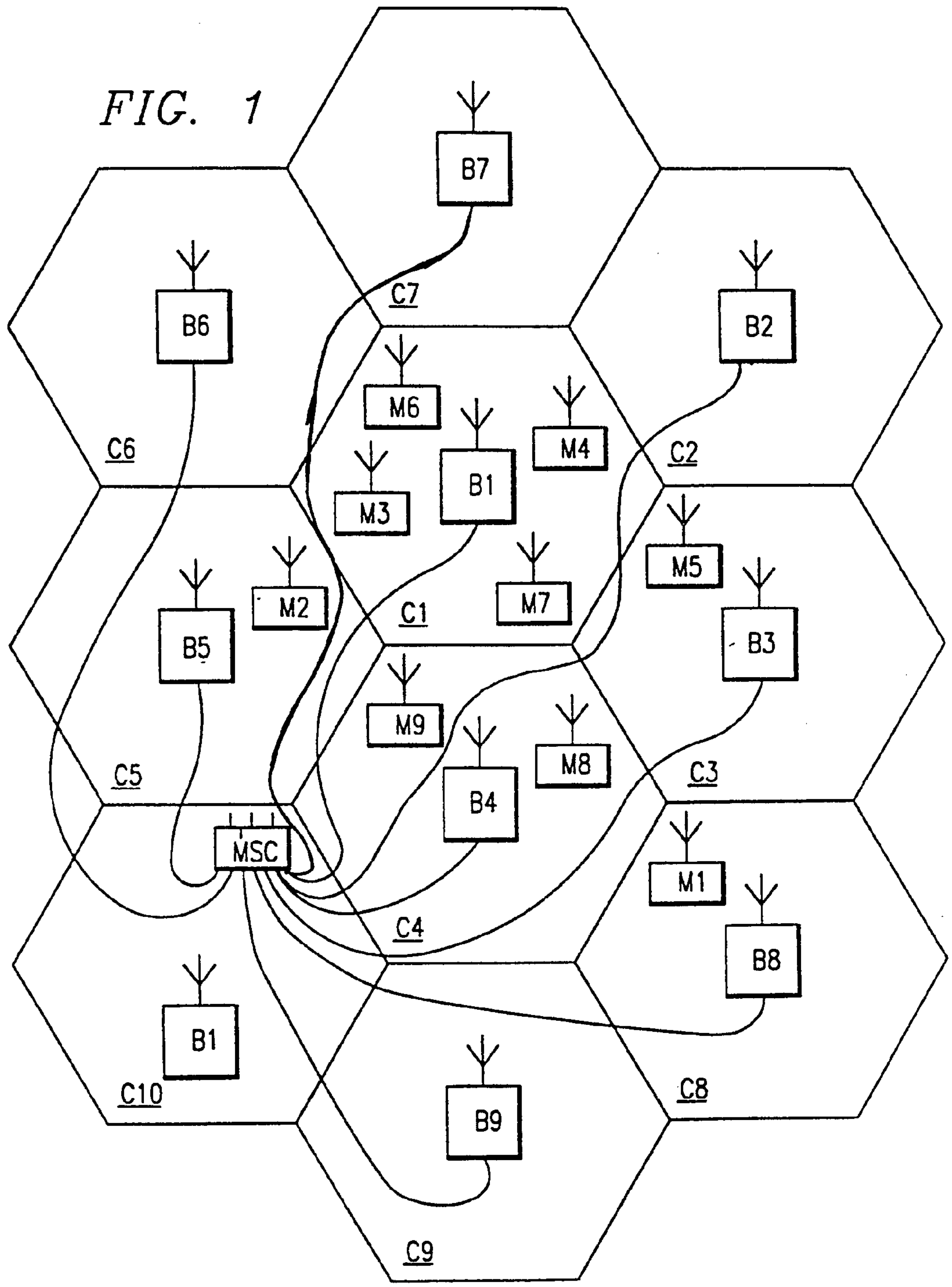
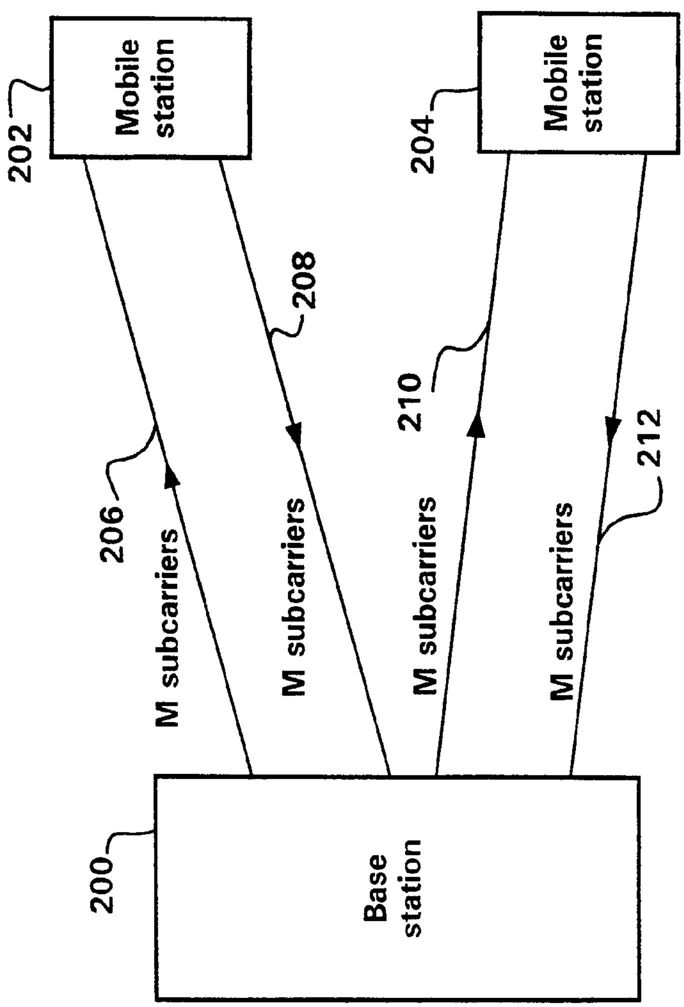

B7
C7
B6
B2
M6
M4
C6
B1
C2
M3
M5
M2
M7
B5
C1
B3
M9
M8
C5
B4
C3
MSC
M1
B8
C4
B1
B9
C10
C8
C9

FIG. 2


Mobile station
202
Mobile station
204
208
206
210
212
M subcarriers
M subcarriers
M subcarriers
M subcarriers
Base station
200

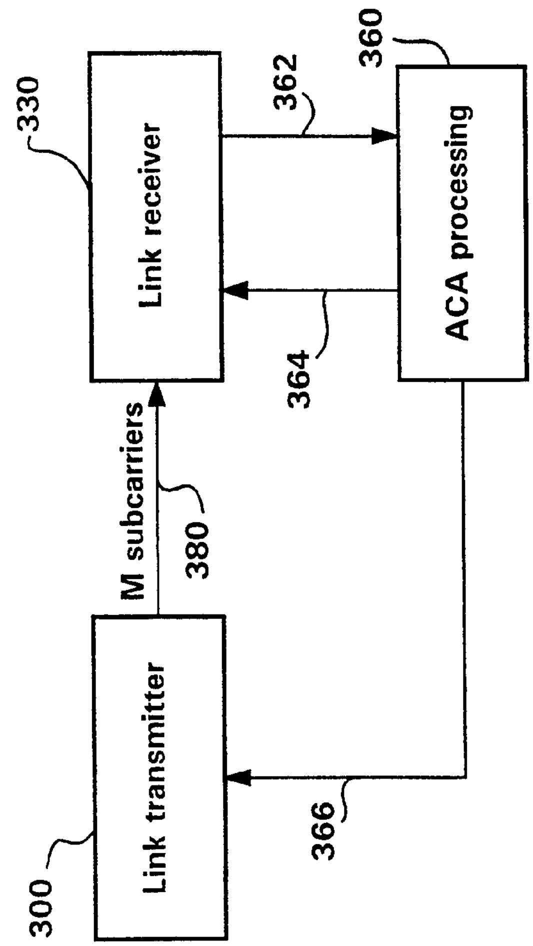
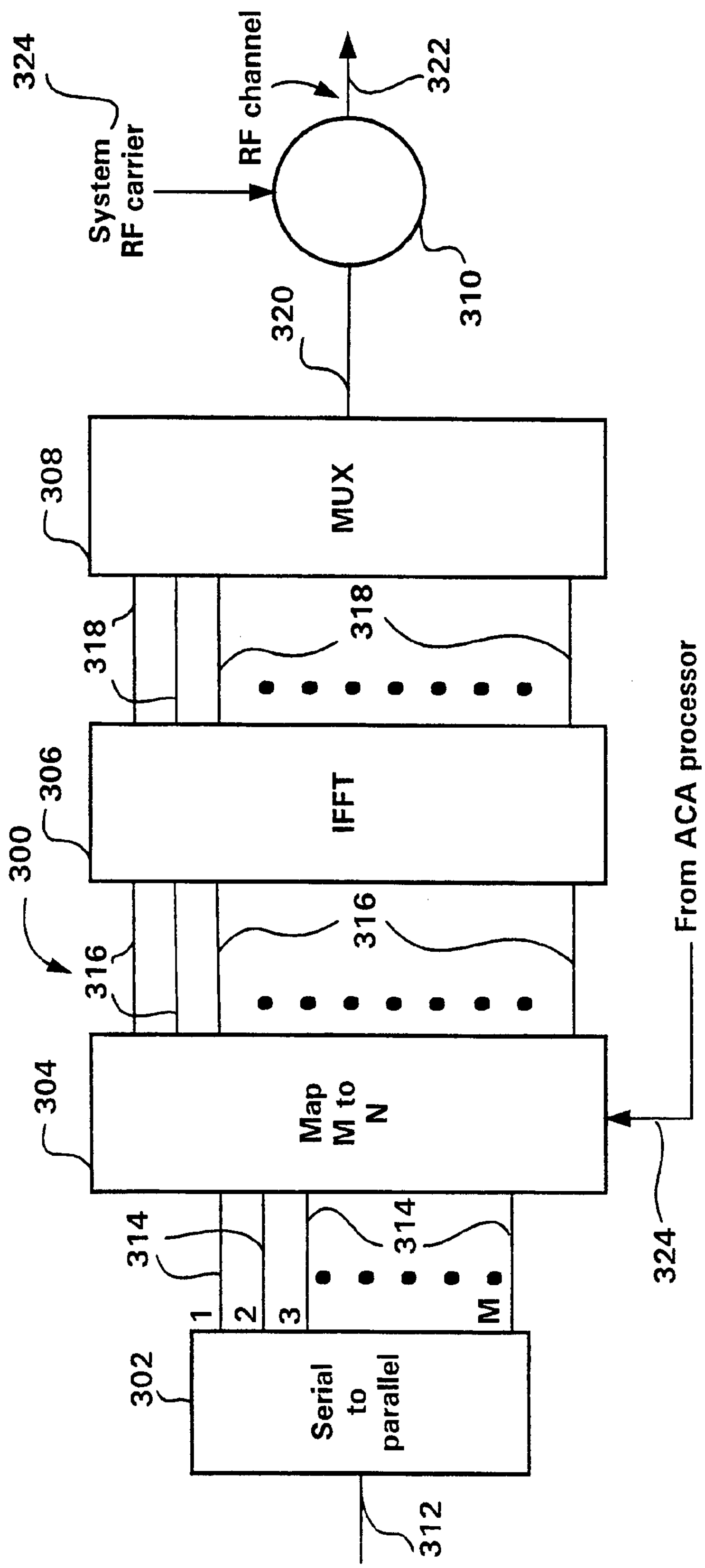

330
Link receiver
362
360
ACA processing
364
M subcarriers
380
Link transmitter
300
366

FIG. 3A

FIG. 3B



324
System
RF carrier
RF channel
322
310
320
308
MUX
318
318
306
IFFT
300
316
316
From ACA processor
304
Map
M to
N
314
314
324
1
2
3
M
302
Serial
to
parallel
312

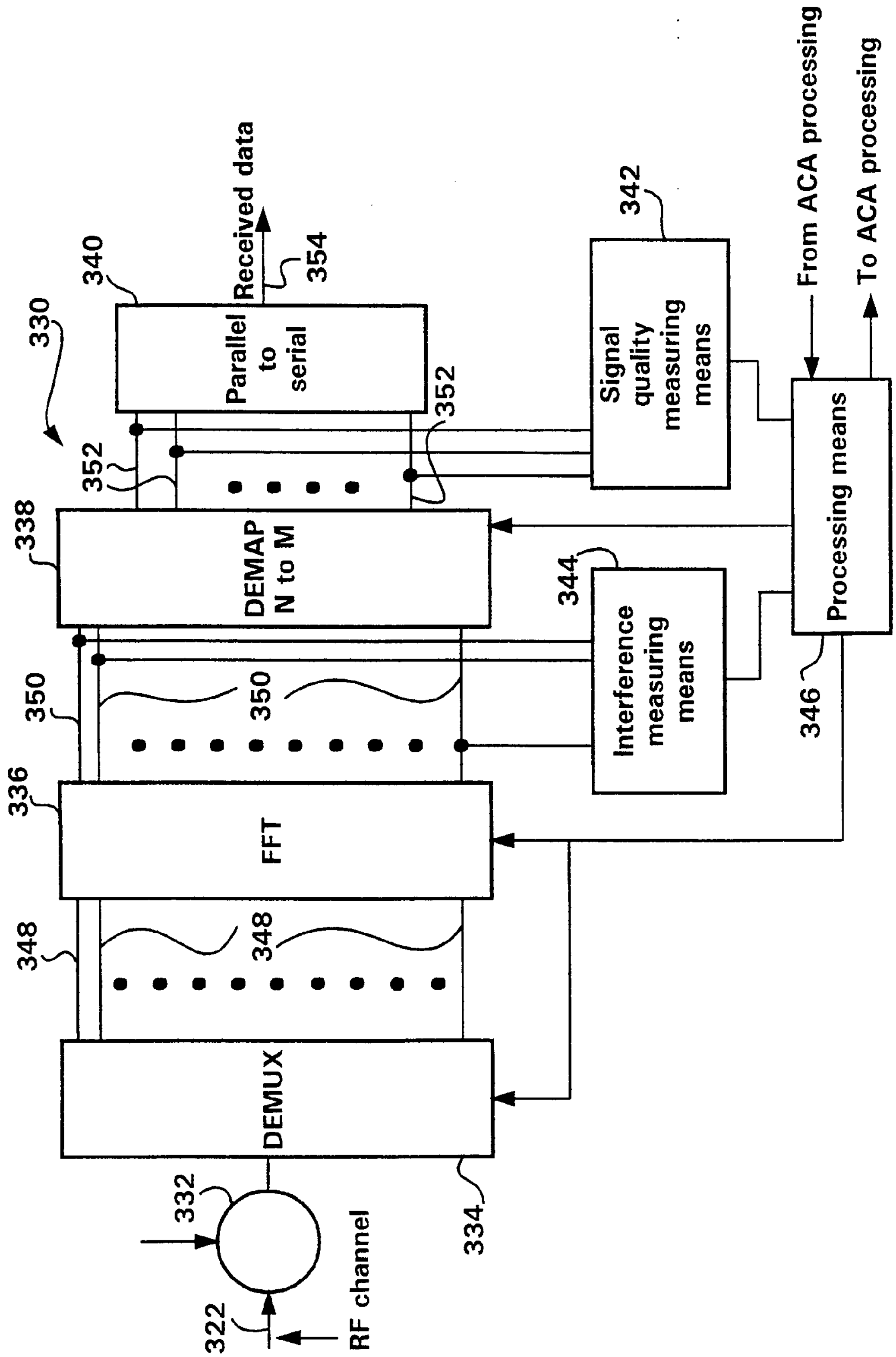

Received data
354
340
330
Parallel to serial
352
352
342
Signal quality measuring means
From ACA processing
To ACA processing
Processing means
338
DEMAP N to M
344
Interference measuring means
346
350
350
336
FFT
348
348
DEMUX
332
334
322
RF channel

FIG. 3C

FIG. 4A

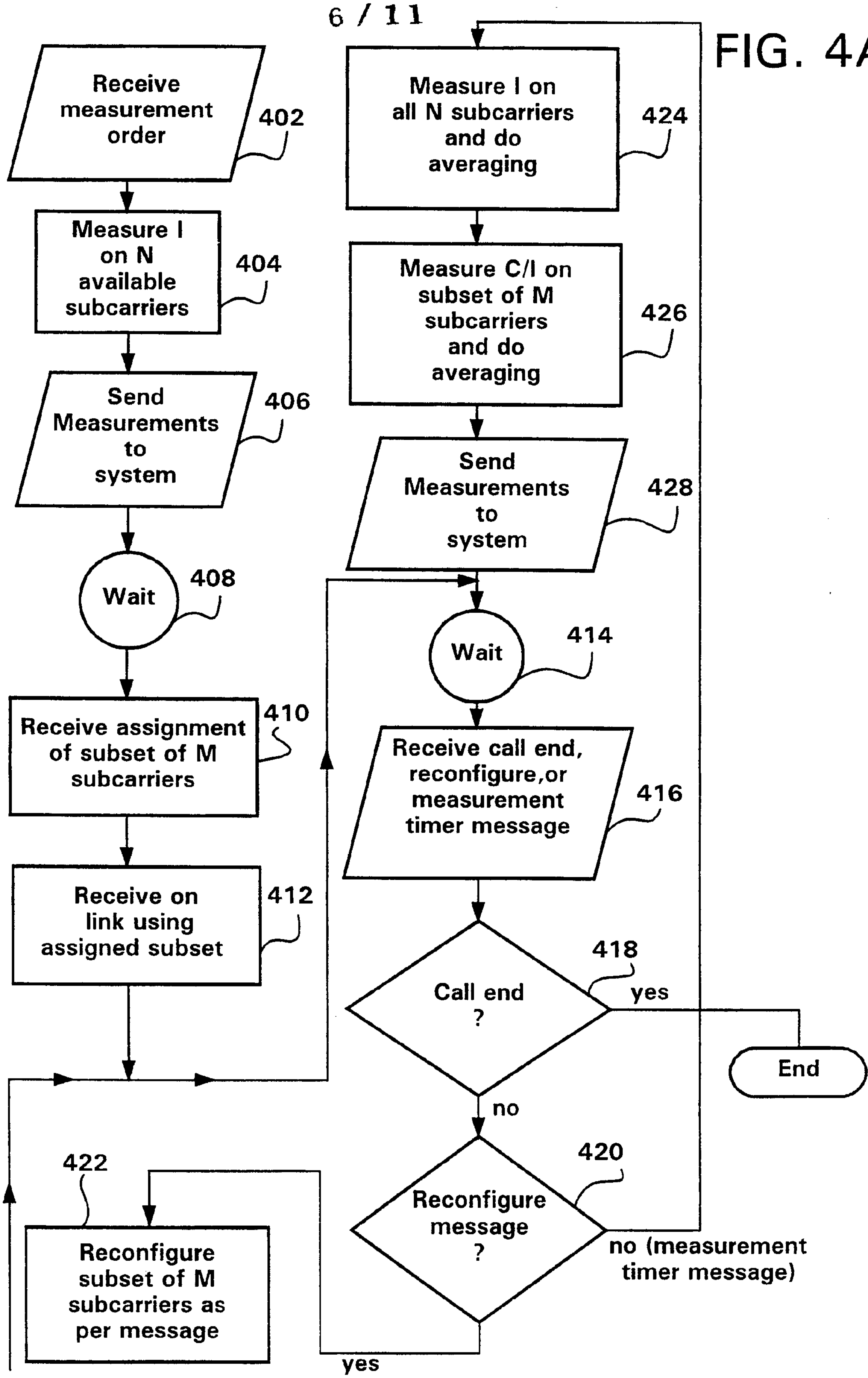

Receive measurement order
402
Measure I on N available subcarriers
404
Send Measurements to system
406
Wait
408
Receive assignment of subset of M subcarriers
410
Receive on link using assigned subset
412
Measure I on all N subcarriers and do averaging
424
Measure C/I on subset of M subcarriers and do averaging
426
Send Measurements to system
428
Wait
414
Receive call end, reconfigure,or measurement timer message
416
Call end ?
418
yes
End
no
Reconfigure message ?
420
no (measurement timer message)
yes
422
Reconfigure subset of M subcarriers as per message

FIG. 4B

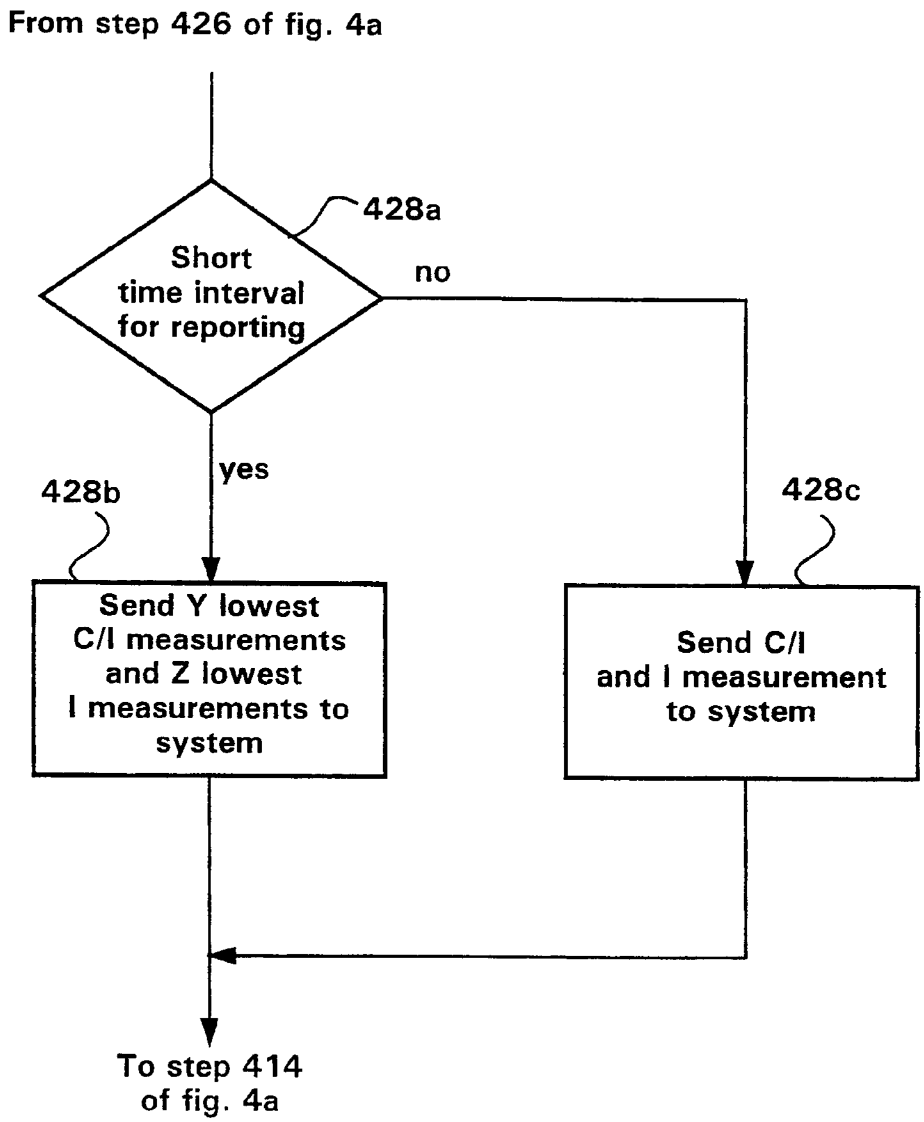
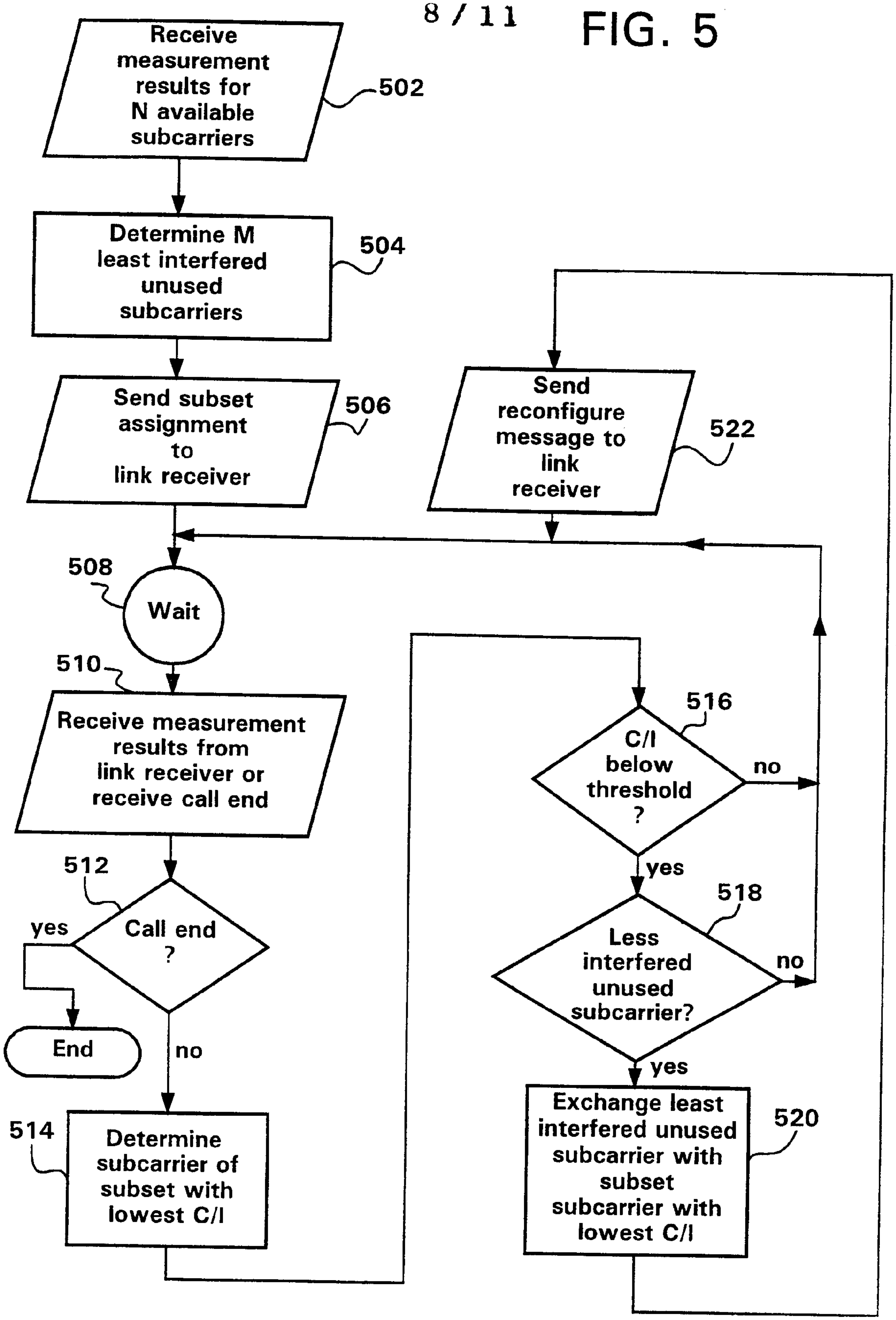

From step 426 of fig. 4a
428a
Short time interval for reporting
no
yes
428b
428c
Send Y lowest C/I measurements and Z lowest I measurements to system
Send C/I and I measurement to system
To step 414 of fig. 4a

FIG. 5



Receive measurement results for N available subcarriers
502
Determine M least interfered unused subcarriers
504
Send subset assignment to link receiver
506
Send reconfigure message to link receiver
522
508
Wait
510
Receive measurement results from link receiver or receive call end
512
Call end ?
yes
no
End
514
Determine subcarrier of subset with lowest C/I
516
C/I below threshold ?
no
yes
518
Less interfered unused subcarrier?
no
yes
Exchange least interfered unused subcarrier with subset subcarrier with lowest C/I
520

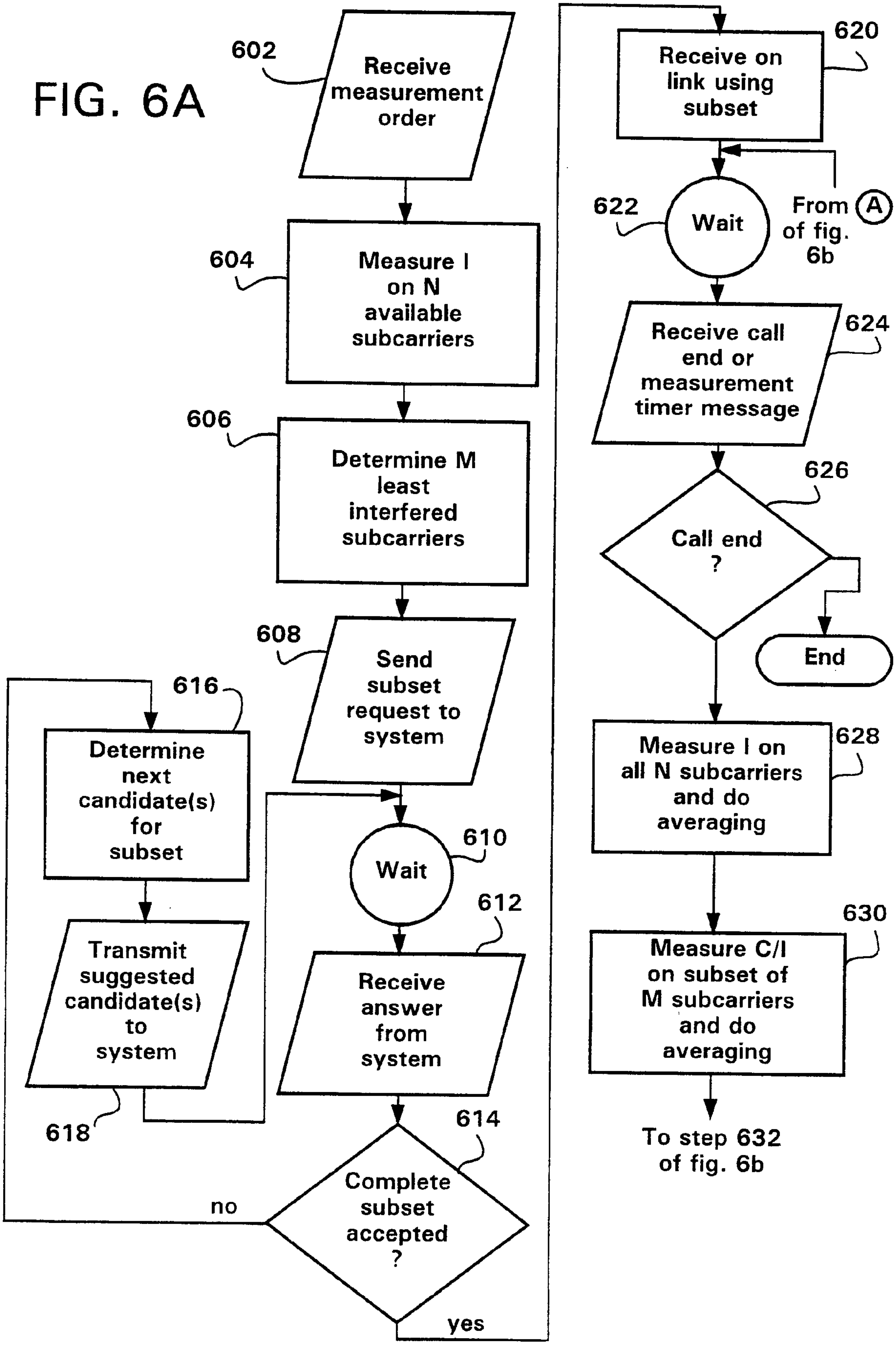

602
Receive measurement order
604
Measure I on N available subcarriers
606
Determine M least interfered subcarriers
608
Send subset request to system
610
Wait
612
Receive answer from system
614
Complete subset accepted ?
no
yes
616
Determine next candidate(s) for subset
618
Transmit suggested candidate(s) to system
620
Receive on link using subset
622
Wait
From A of fig. 6b
624
Receive call end or measurement timer message
626
Call end ?
End
628
Measure I on all N subcarriers and do averaging
630
Measure C/I on subset of M subcarriers and do averaging
To step 632 of fig. 6b

FIG. 6A

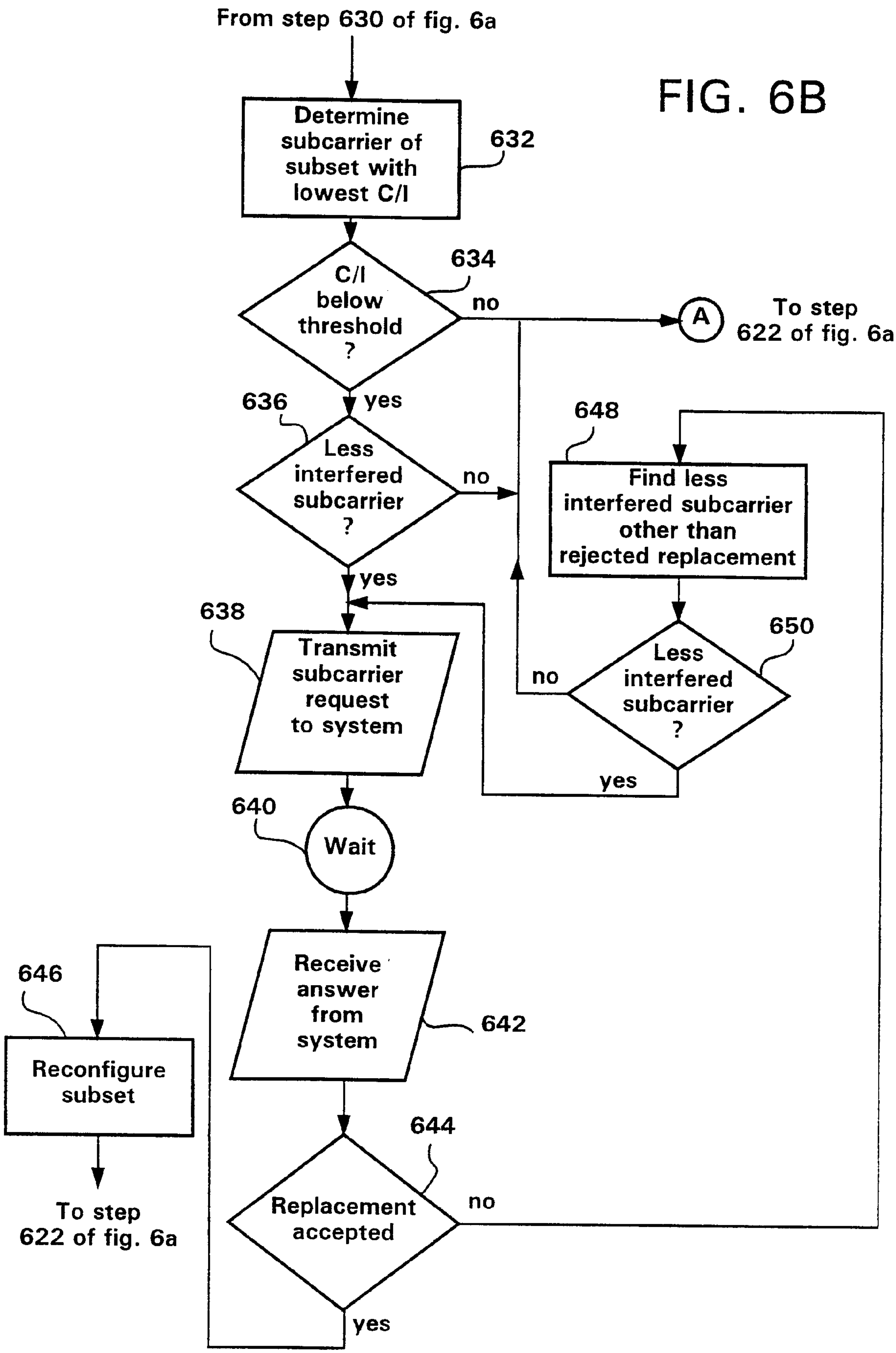
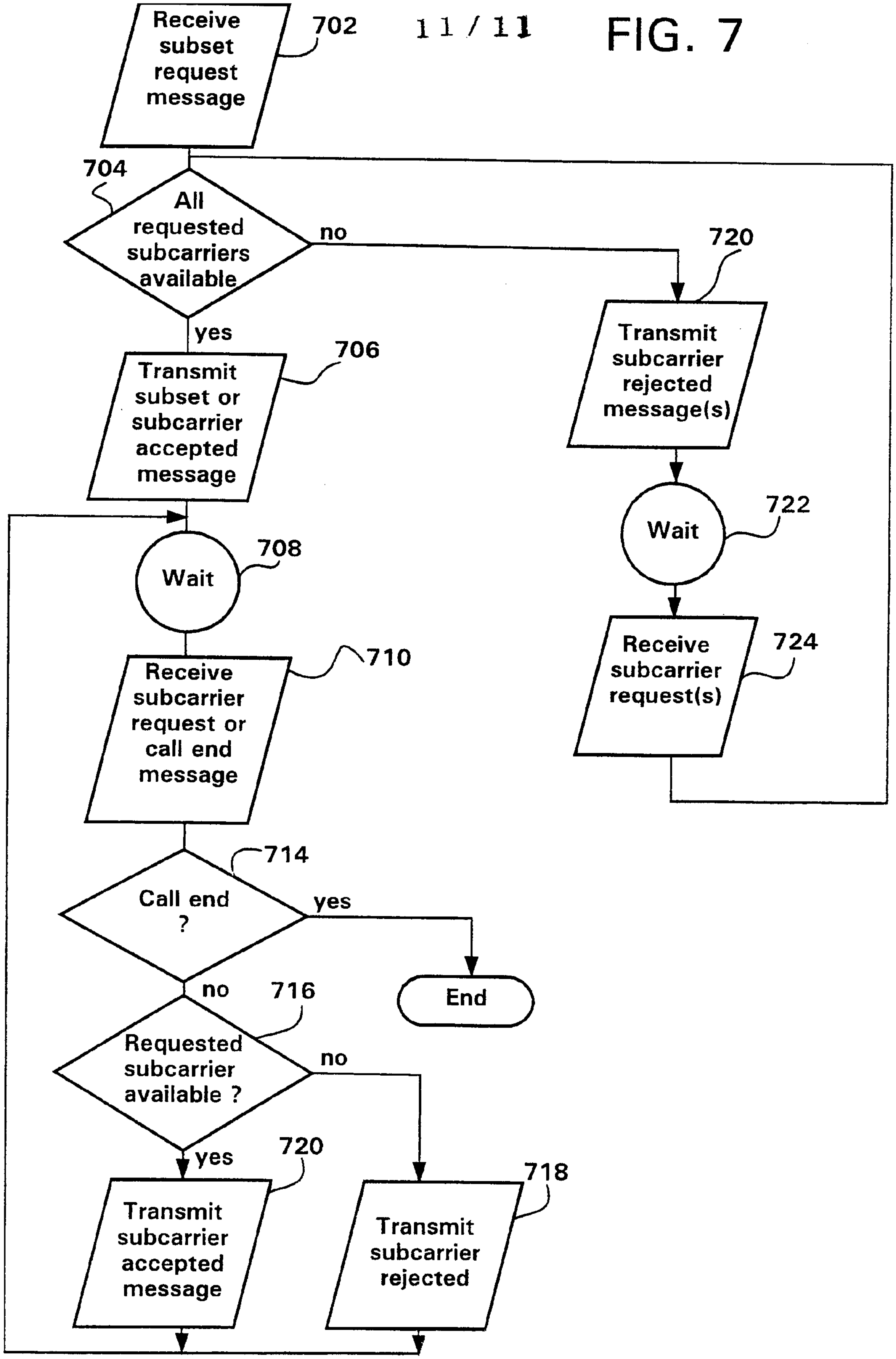

From step 630 of fig. 6a
Determine subcarrier of subset with lowest C/I
632
634
C/I below threshold ?
no
A
To step 622 of fig. 6a
yes
636
Less interfered subcarrier ?
no
648
Find less interfered subcarrier other than rejected replacement
yes
638
650
Transmit subcarrier request to system
no
Less interfered subcarrier ?
yes
640
Wait
646
Receive answer from system
642
Reconfigure subset
644
To step 622 of fig. 6a
Replacement accepted
no
yes

FIG. 6B

FIG. 7


Receive subset request message
702
704
All requested subcarriers available
no
720
Transmit subcarrier rejected message(s)
yes
706
Transmit subset or subcarrier accepted message
Wait
722
708
Wait
Receive subcarrier request(s)
724
Receive subcarrier request or call end message
710
714
Call end ?
yes
End
no
716
Requested subcarrier available ?
no
yes
720
718
Transmit subcarrier accepted message
Transmit subcarrier rejected

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SE 96/00814

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/38 H04L5/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,95 10144 (TELIA AB ;ENGSTROEM BO (SE); LARSSON ROGER (SE)) 13 April 1995 see the whole document ---	1-10, 14-23
A	US,A,5 295 138 (GREENBERG A FREDERICK ET AL) 15 March 1994 see claims ---	1-26
A	US,A,5 400 322 (HUNT RONALD R ET AL) 21 March 1995 see column 1, line 31 - column 3, line 63 ---	1-5, 8-10, 14-18, 21-23
A	EP,A,0 637 181 (SIEMENS AG) 1 February 1995 see the whole document --- -/--	1-5, 14-18

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

Date of the actual completion of the international search	Date of mailing of the international search report
22 October 1996	12.11.96
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Janyszek, J-M

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ELECTRONICS LETTERS, 27 OCT. 1994, UK, vol. 30, no. 22, ISSN 0013-5194, pages 1831-1832, XP000490811 CHAN C -K ET AL: "Efficient frequency assignment scheme for intermodulation distortion reduction in fibre-optic microcellular systems" see the whole document ---	1-7, 14-18,20
A	EP,A,0 490 509 (NORTHERN TELECOM LTD) 17 June 1992 see the whole document -----	1-8, 14-22

2

INTERNATIONAL SEARCH REPORT

ormauon on patent family members

International Application No
PCT/SE 96/00814

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9510144	13-04-95	SE-C-	503548	01-07-96
		EP-A-	0721705	17-07-96
		SE-A-	9303213	02-04-95
US-A-5295138	15-03-94	NONE		
US-A-5400322	21-03-95	NONE		
EP-A-0637181	01-02-95	DE-A-	4325190	02-02-95
		FI-A-	943525	28-01-95
EP-A-0490509	17-06-92	CA-A-	2032325	15-06-92
		US-A-	5239676	24-08-93

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04Q 7/38, 7/22 | A2

(11) International Publication Number: WO 98/35525

(43) International Publication Date: 13 August 1998 (13.08.98)

(21) International Application Number: PCT/US98/02524

(22) International Filing Date: 10 February 1998 (10.02.98)

(30) Priority Data:
798,949 11 February 1997 (11.02.97) US

(71) Applicant: QUALCOMM INCORPORATED [US/US]; 6455 Lusk Boulevard, San Diego, CA 92121 (US).

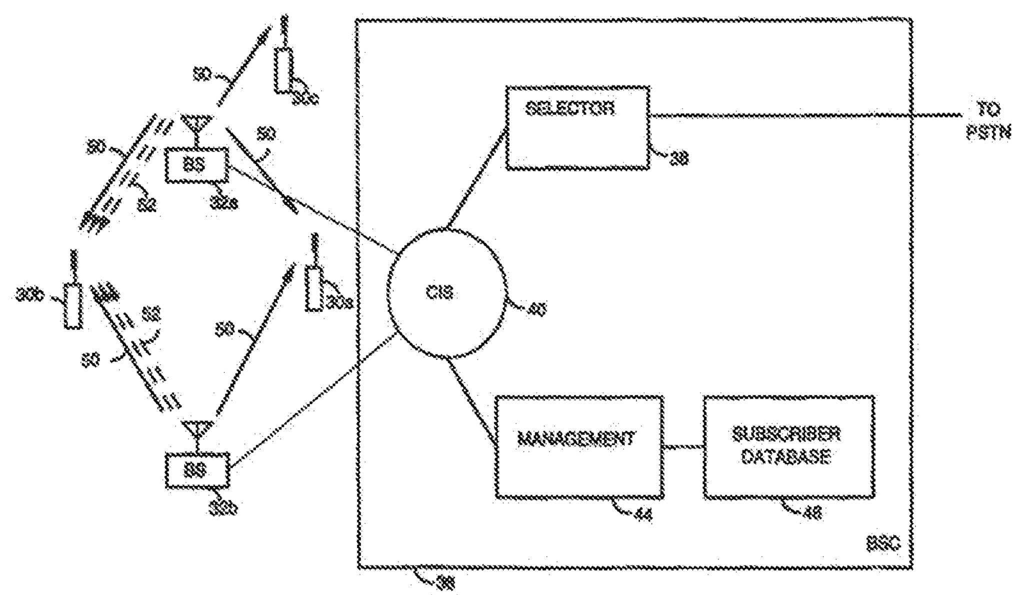
(72) Inventors: TIEDEMANN, Edward, G., Jr.; 4350 Bromfield Avenue, San Diego, CA 92121 (US). JOU, Yu-Cheun; 9979 Riverhead Drive, San Diego, CA 92129 (US).

(74) Agents: OGROD, Gregory, D. et al.; Qualcomm Incorporated, 6455 Lusk Boulevard, San Diego, CA 92121 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: A METHOD OF AND APPARATUS FOR CONTROLLING HANDOFF IN A COMMUNICATION SYSTEM



(57) Abstract

A method and apparatus for controlling the transmit power of a high rate code division multiple access (CDMA) link is described. The channel condition to a subscriber unit (30a, 30b, 30c) is evaluated and the configuration of a high rate link in soft handoff is based on the channel condition. If a fading channel is detected the supplemental channels (52) of the high rate link are transmitted from multiple base stations (32a, 32b). If a non-fading channel is detected the supplemental channels of the high rate link are transmitted from a single base station. Parameters monitored to determine the channel condition include the pilot strength, pilot code offset and error rate.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

A METHOD OF AND APPARATUS FOR CONTROLLING HANDOFF IN A COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to wireless telecommunications. More particularly, the present invention relates to a method of and apparatus for controlling handoff in a communication system.

II. Description of the Related Art

FIG. 1 is a schematic diagram of a cellular telephone system configured in accordance with the use of the IS-95 over-the-air interface standard. The IS-95 standard, and its derivatives such as IS-95-A, IS-99, IS-657 and ANSI J-STD-008 etc. (referred to herein collectively as the IS-95 standard), define an interface for implementing a digital cellular telephone system using code division multiple access (CDMA) signal processing techniques. Also, a cellular telephone system configured substantially in accordance with the use of IS-95 is described in US patent 5,103,459 entitled "System and Method for Generating Signal Waveforms in a CDMA Cellular Telephone System" assigned to the assignee of the present invention and incorporated herein by reference.

As is typical for most cellular telephone systems, IS-95 allows mobile telephone service to be provided using a set of base stations **12** coupled to the public switched telephone network (PSTN) **18** by a base station controller (BSC) **14** and a mobile switching center (MSC) **16**. During a telephone call, a subscriber unit **10** (typically a cellular telephone) interfaces with one or more base stations **12** using CDMA modulated radio frequency (RF) signals. The RF signal transmitted from the base station **12** to the subscriber unit **10** is referred to as the forward link, and the RF signal transmitted from the subscriber unit **10** to the base station **12** is referred to as the reverse link.

Unlike most other cellular telephone systems, IS-95 communication systems are capable of performing soft handoff when a subscriber unit **10** transitions from the coverage area of a first base station **12** to the coverage area of a second base station **12**. In soft handoff, the subscriber unit **10** establishes a communication link with the second base station **12** before terminating the communication link with the first base station. Thus, soft handoff requires simultaneously interfacing with both the first and second

base stations 12, which is the condition of subscriber unit **10b** as shown in FIG. 1. The preferred embodiments for performing soft handoff are described in US Patent No. 5,267,261 entitled "Mobile Station Assisted Soft Handoff in a CDMA Cellular Communications System" assigned to the assignee of the present invention and incorporated herein by reference. Soft handoff can be contrasted with hard handoff in which the link with the first base station is terminated before the link with the second base station is established.

Soft handoff is generally necessary in a CDMA based cellular telephone system because adjacent base stations transmit in the same RF band, and the interference between the two forward link signals at the border of the coverage areas fluctuates rapidly and unpredictably. The fading caused by this interference results in a poor received signal to noise ratio at the subscriber unit **10**, which further results in either a higher required transmit power from the base station **12**, or a higher error rate, or a combination thereof. During soft handoff, both the first and second base stations **12** transmit copies of the user data directed to subscriber unit **10** to provide signal source diversity. Thus, if one base station **12** fades relative to the other base station **12**, the subscriber unit **10** still receives one signal properly. Also, the two forward link signals can be combined at the subscriber unit **10**, which can result in proper reception even when neither forward link signal alone was received at a sufficient level.

It should be noted that soft handoff can also involve three or more base stations **12**, all transmitting copies of the data directed to subscriber unit **10**. In general, the signal diversity provided by soft handoff makes it more robust than hard handoff, in that the call is less likely to be dropped.

Although soft handoff has the advantage of being more robust than hard handoff, it has the disadvantage of requiring two or more transmissions of the same user data. Within an IS-95 compliant or other type of CDMA cellular telephone system, these multiple transmissions may increase or decrease overall capacity of the cellular telephone system. Whether there is an increase or decrease depends of the fading condition for the subscriber unit **10**.

More recently, however, it has become desirable to provide higher transmission rate communication services in conjunction with the mobile telephone service already provided by an IS-95 cellular telephone system. Examples of such higher rate links are described in copending US Patent Applications Serial No. 08/656,649 filed May 31, 1996 entitled "Method and Apparatus for Providing Rate Scheduled Data in a Spread Spectrum Communication System and Serial No. 08/784,281 entitled "High Data Rate

Supplemental Channel for CDMA Telecommunications System" filed January 15, 1997 both assigned to the assignee of the present invention and incorporated herein by reference (high data rate patent applications).

These higher rate communications are transmitted with substantially greater power than the typical voice based communications, which substantially increases the negative impact of generating multiple transmissions as during a soft handoff. Since it is nonetheless desirable to allow a subscriber unit 10 conducting a high speed communication to transition between the coverage areas of different base stations 12, an alternative method and apparatus for performing handoff is required.

SUMMARY OF THE INVENTION

The capacity of a CDMA cellular telephone system is maximized if the transmit power for each communication is minimized while maintaining the same error rate. When fading is present during a soft handoff transmitting the forward link signal from two base stations usually results in the least total amount of power, where the total amount of power is the sum of the powers radiated by the base stations to the subscriber unit. When fading is not present during soft handoff, transmitting the forward link signal from one base station uses the least amount of power, as no benefit is gained from signal source diversity.

There have been a few proposals to increase the transmission data rate of an IS-95/ANSI-J-008 based CDMA cellular/PCS system. Two preferred methods for increasing the available data rates of forward link transmission of CDMA communication systems are disclosed in the aforementioned high data rate patent applications. In order to increase the data rate on the forward link, multiple Walsh code channels are combined to transmit data to one user. In a first embodiment for transmitting high speed data over the forward link, a plurality of Walsh channels conforming to the IS-95 standard independently carry portions of the data stream to the remote high speed data receiver. In the alternative, a high speed data channel can be provided wherein the high speed data channel is generated by a combination of available Walsh channels to provide an equivalent code channel spread by a shorter Walsh code. For either case, a high data rate user is assigned a fundamental code channel which carries signaling messages and the reverse link power control subchannel in addition to data traffic. In addition, the high data rate user is also assigned one or more supplemental code channels which carries data traffic only

when transmitted in accordance with the methods described above. The supplemental code channels may comprise a set of Walsh code channels being transmitted to the remote high speed receiver other than the fundamental channel. The supplemental code channels may alternately comprise a combination of Walsh channels used to provide a shortened Walsh channel.

In many cases, data users are stationary. When a subscriber unit is stationary, soft handoff does not provide any performance gain on the forward link. When a subscriber unit is receiving high speed digital data, only the base station which is best received by the subscriber unit should transmit data to this subscriber unit in order to optimize the use of forward link capacity. However, when a subscriber unit is non-stationary, soft handoff usually provides performance gain on the forward link. In that case, there may be an advantage to transmit data to the subscriber unit from multiple base stations. Thus, one goal of the present invention is to detect if a subscriber unit is stationary and if so to prevent the subscriber unit from entering into soft handoff. Additionally, even when the subscriber unit is non-stationary, there are situations when only the base station which is being received the strongest at the subscriber unit should be transmitting to the subscriber unit in order to maximize capacity. This typically happens when there is sufficient multipath from a particular base station. The invention aims to determine when it is preferable for a single base station to transmit to a non-station subscriber unit.

The present invention seeks to optimize the performance of a CDMA cellular telephone system by conducting the soft handoff in the most efficient state based on the channel condition being experienced by the subscriber unit.

According to one aspect of the invention there is provided a method of controlling handoff in a communication system in which data is transmitted to a remote station by providing a first subset of said data on a fundamental channel and a second subset of said data on at least one supplemental channel, the method comprising: receiving a pilot strength measurement message from said subscriber unit; selecting a plurality of base stations for providing transmissions to said subscriber unit on said fundamental channel based on said pilot strength measurement message; and independently selecting at least one of said plurality of base stations for providing transmissions to said subscriber unit on said at least one supplemental channel.

According to another aspect of the invention there is provided an apparatus for controlling hand-off of a subscriber unit between a plurality of base stations, the apparatus comprising: means for controlling transmission of data in a fundamental channel and in supplemental channels; and means for selecting plural base stations for transmission of data in the fundamental channel and for selecting one or more of the plural base stations for transmission of data in the supplemental channel.

The invention also provides a method of controlling hand-off of a subscriber unit between a plurality of base stations, the method comprising: controlling transmission of data in a fundamental channel and in supplemental channels; selecting plural base stations for transmission of data in the fundamental channel; and selecting one or more of the plural base stations for transmission of data in the supplemental channel.

In a first embodiment of the present invention, the communication system provides for independent handoff of the fundamental code channel and supplemental code channels on the forward link. Because there are different performance requirements on the fundamental code channel and supplemental code channels, allowing the fundamental code channel to be in soft handoff without the supplemental code channel being in soft handoff provides flexibility to optimize the use of the forward link for high speed data transmission. In a preferred embodiment, the reverse link is in soft handoff (i.e., subscriber unit transmission is received by multiple base stations) whenever any forward link channel is in soft handoff.

In another exemplary embodiment, the fundamental code channel is placed in soft handoff (i.e., transmitting the same data bits from more than one base stations) using the same handoff criteria described in IS-95 and the aforementioned U.S. Patent No. 5,267,261, while putting supplemental code channels in soft handoff only under certain conditions. When the supplemental code channel is not in handoff, the supplemental code channels are only transmitted by the base station with the strongest pilot received at the subscriber unit. In order to implement the independent handoff of the supplemental and fundamental code channels, the Extended Handoff Direction Message, which directs the subscriber unit to the base stations currently transmitting data to it, should

separately specify the base stations (or pilot PN offsets) transmitting the fundamental code channel and supplemental code channels.

In the following description there is disclosed a set of criteria that can be used to determine when to put supplemental code channels in soft handoff. The criteria include:

1. When the content (pilots, PN phases, and pilot strengths) of the Pilot Strength Measurement Message sent by the subscriber unit changes.
2. When the strength of the pilot used for the supplemental code channels changes significantly.
3. When the best base station (the one with the strongest pilot received at the subscriber unit) changes frequently.
4. When the sum of the strength of all the pilots received by the subscriber unit changes significantly.
5. When the error indicator bit (EIB) bit received in the reverse link frame flips, indicating that a forward link frame has been received in error.
6. When the quality of the reverse link frames received from different Active Set members alternate (i.e., the selector frequently selects received frames from different base stations in soft handoff).
7. When the mobile station, using its pilot filters, reports the relative strength of one pilot to another. This tells the base station which pilot channels should be in the Active Set for the supplementary channel.
8. When the strength of a pilot channel from a base station transmitting the fundamental channel increases relative to the strength of the pilot channel from a base station transmitting the high speed link

Better forward link power control also results in larger forward link capacity. Thus, it is an objective of the present invention to describe an improved method for controlling the transmit power of the fundamental code channel and supplemental code channels to increase forward link capacity. It is envisioned that the supplemental code channels may be transmitted at a different power level than the fundamental code channel. For example, since the data can be

retransmitted upon detection of an error, the supplemental code channels — which carry data only, no signaling messages — may be transmitted at a lower power than the fundamental code channel. In this case, while the frame error rate (FER) on the supplemental code channels may be permitted to be higher, the data packet error rate with the availability of retransmissions will be the same as or even lower than the FER on the fundamental code channel in the absence of retransmission. In alternative applications, such as data applications requiring very low error rate, the supplemental code channels may be transmitted at a higher power level than the fundamental code channel.

The transmit power of the fundamental code channel may be controlled using the same forward power control method defined in IS-95 and ANSI-J-008. The supplemental code channels are transmitted at a power level with an adjustable offset (in dB) from the power of the fundamental code channel. The power of the supplemental code channels as well as the power of the fundamental code channel change the same incremental amount in response to the forward power control (therefore, the offset between the two remains unchanged). When the channel condition changes, the offset is adjusted in order to maintain a target FER on the supplemental code channel.

The criteria described above can be used to detect changes in channel condition. In addition, a message similar to the Power Measurement Report Message can be defined for reporting frame errors on the supplemental code channels. The NAK generated by the radio link protocol (RLP) set forth in IS-99 and described in greater detail below, as a result of a missing frame, can also be used to indicate received frame errors. The estimated FER can be used in turn to trigger the adjustment of the offset.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and furtherfeatures of the present invention are set forth with particularity in the appended claims and togehter with further advantages thereof will become more apparent from the detailed description of embodiments of the invention which is given by way of example only with reference to the accompanying drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a block diagram of a cellular telephone system;

FIG. 2 is a block diagram of a cellular telephone system configured in accordance with one embodiment of the invention; and

FIG. 3 is a flow diagram illustrating the operation of a cellular telephone system in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A method of and apparatus for controlling the transmit power necessary for the proper operation of a high rate link is described. In the following description, an embodiment of the invention is set forth in the context of a CDMA cellular telephone system operating in accordance with the IS-95 standard. While the invention is especially suited for operation with a cellular telephone system operating in accordance with the IS-95 standard, other wireless communication systems where interference reduction is desirable may incorporate the use of the present invention, including satellite based telecommunications systems.

FIG. 2 is a block diagram of a portion of cellular telephone system configured in accordance with an exemplary embodiment of the invention. Subscriber units **30a**, and **30b** have established bi-directional links with both base stations **32a** and **32b** and therefore are in soft handoff, while subscriber unit **30c** is only interfacing with base station **32a** and therefore is engaged in a single link interface. Base stations **32a** and **32b** are coupled to CDMA interconnect subsystem (CIS) **40** via wire line connections.

CIS **40** is located within base station controller (BSC) **36** and is coupled to selector subsystem **38** and management system **44**. Management system **44** is coupled to subscriber database **46**. The various systems that make up BSC **36**, as well as base stations **32**, exchange data and control information via the use of network packets which contain an address that allows routing by CIS **40**. During operation, management system **44** configures and controls selector subsystem **38** and base stations **32** using subscriber information contained in subscriber data base **46**.

In accordance with one embodiment of the invention, the forward link signal from base stations **32a** and **32b** is comprised of a set of subsignals referred to as channels. The channels are formed by modulation of the transmitted data with one of a set of sixty-four orthogonal Walsh codes, which is consistent with the use of IS-95. Thus, up to sixty-four forward link channels maybe transmitted within the forward link signal.

The forward link channels include a pilot channel which facilitates acquisition and processing of the forward link signal, as well as a set of traffic channels which are used to conduct the forward link portion of the telephone call or other communication with a subscriber unit 30. Both the signaling and traffic data transmitted over the various channels is formatted and processed in frames.

In the configuration shown, subscriber unit 30a is conducting a conventional, IS-95 style, lower rate bi-directional voice or data communication, and subscriber unit 30b is conducting a higher rate forward link communication combined with a lower rate reverse link communication in accordance with the high data rate links described in the above referenced high data rate patent applications. In accordance with this configuration, base stations 32a and 32b allocate a single forward link traffic channel designated as a fundamental channel 50 for communication with subscriber unit 30a. To establish the high rate communication with subscriber unit 30b, base stations 32a and 32a allocate a set of forward link traffic channels which are designated as a fundamental channel 50 and a set of supplemental channels 52. Supplemental channels 52 are shown as dashed lines because, as described below, the are not always transmitted from both base stations 32 during soft handoff.

In a preferred embodiment of the invention, the fundamental channel can be used to transmit both signaling data as well as primary and secondary traffic data, and the supplemental channel can be used to transmit primary or secondary traffic data, but not signaling data. Primary and secondary traffic data denote two subchannels for simultaneously transmitting two different types of user data such as voice and digital data.

In the preferred embodiment of the invention the fundamental channel is processed in the same or a similar manner as the conventional lower rate IS-95 forward link channel. Also, the supplemental channel is preferably generated in accordance with one of the above referenced high data rate patent applications.

In the preferred embodiment of the invention, the reverse link signals from both subscriber units 30a and 30b are comprised of a single lower rate channel. As is the case for an IS-95 system, the reverse link channel is formed via modulation of the transmitted data with a longer channel code that is unique to each subscriber unit 30. Additionally, for one of the possible transmission rates provided by IS-95 (typically referred to as Rate Set two) an error indicator bit (EIB) is included in each reverse link

frame that indicates whether the last forward link frame was received correctly.

Higher rate reverse link signals may also be used. An example of a high rate reverse link signal is described in copending US Patent applications Serial No. 08/766,372 entitled "Phase Shift Encoded Subchannel" and Serial No. 08/654,433 entitled "High Data Rate CDMA Wireless Communication System" both assigned to the assignee of the present invention and incorporated herein by reference.

The data frames received by base station **32a** via the reverse link signal are routed as network packets by CIS **40** to selector subsystem **38**. Selector subsystem **38** allocates a selector resource for each call being processed. In the preferred embodiment of the invention, a selector resource is a microprocessor executing a set of software instructions (not shown).

For subscriber unit **30a**, which is operating in the conventional lower rate mode, soft handoff is conducted in the conventional fashion. That is, both base stations **32a** and **32b** allocate a fundamental channel **50** for transmission of the same forward link data to subscriber unit **30a**. Additionally, base stations **32a** and **32b** both attempt to process the reverse link signal from subscriber unit **30a** thereby generating received data frames that are forwarded to selector subsystem **38** within BSC **36**. A system and method for performing soft handoff is also described in US Patent 5,101,501 entitled "Method and System for Providing a Soft Handoff in Communications in a CDMA Cellular Telephone System" assigned to the assignee of the present invention and incorporated herein by reference.

The selector resource within selector subsystem **38** assists in conducting the conventional soft handoff by performing both frame selection and frame distribution. Frame selection is the repeated selection of one of the two reverse link frames received from base stations **32a** and **32b** based on quality indication information contained in each network packet. The selected frame is devocoded and forwarded to MSC **16** (**FIG. 1**) for further processing.

Frame distribution is the repeated duplication and distribution of forward link frames to base stations **32a** and **32b** for transmission to subscriber unit **30a**. As noted above, more than two base stations **32** can be involved in a soft handoff, and thus frame selection and frame distribution can involve the repeated processing of more than two frames.

The selector resource further assists in processing the conventional soft handoff by exchanging signaling messages with subscriber unit **30a** in

order to orchestrate the soft handoff. One such signaling message is a Pilot Strength Measurement Message (PSMM) which is generated by the subscriber unit 30 and received by the selector resource. The PSMM lists the set of pilot channels detected during repeated searches performed by subscriber unit 30a including the signal strength and PN phase at which each pilot channels was received. The PSMM provides an indication of the set of base stations 32 that subscriber unit 30a can successfully communicate with. In a preferred embodiment of the invention, a PSMM is generated when the strength and duration of a pilot channel changes in accordance with that described in US Patent No. 5,267,261 referenced above.

In response to the PSMM the selector resource determines if a soft handoff is necessary and if so, transmits an Extended Handoff Direction Message (EHDM) to the subscriber unit 30a. Additionally, the selector instructs the target base station 32 (i.e. the base station from which the new RF interface is being established) to begin searching for the reverse link signal from the subscriber unit 30. Also, the selector resource instructs the target base station 32 to allocate a forward link traffic channel for establishing the fundamental channel, and to begin transmitting forward link frames to the subscriber unit via the fundamental channel. Once the reverse link signal has been acquired by the target base station 32 then both base stations 32 are receiving and processing the reverse link signal from subscriber unit 30b.

In accordance with the preferred embodiment of the invention, all base station 32 transmitting the fundamental channel will receive and process the reverse link signal. As noted above, while this exemplary embodiment of the invention describes a soft handoff using two base stations 32, soft handoffs can involve more than two base stations 32. At this point, the soft handoff reaches steady state condition where both base stations 32 transmit the forward link channel and receive the reverse link channel.

As noted above, subscriber unit 30b is engaged in a high speed forward link which includes a fundamental channel and a set of one or more supplemental channels. In accordance with one embodiment of the invention, the transmission of the fundamental channel and the supplemental channels from base stations 32a and 32a are controlled independently from one another during soft handoff. In the implementation of the invention described herein, it is the selector resource processing the communication with subscriber unit 30b that performs the control as described below.

In accordance with an exemplary embodiment of the invention, the selector resource tracks the Pilot Strength Measurement Messages (PSMM) as they are received from subscriber unit 30b. Also, as practiced in IS-95 compatible systems, a PSMM contains three parameters for each pilot channel being reported on. The parameters includes the strength of the pilot channel, the PN phase of the pilot channel, and the identity of the pilot channel. The identity is provided as a PILOT_PN offset that is unique for each pilot channel in a given area.

The selector resource monitors the behavior of the parameters as reported over a set of PSMM's. Additionally, the selector resource monitors each PSMM to determine if a soft hand off is necessary in accordance with the above referenced '261 patent. When it is determined that a soft handoff is necessary, the selector resource adjusts the manner in which the soft handoff is conducted for the high rate link based on the behavior detected in any one of the three parameters.

In a preferred embodiment of the invention, when the behavior detected over a set of PSMM's indicates that a non-fading (typically a static multipath or additive white Gaussian noise (AWGN)) channel exists to subscriber unit 30b, the high speed link can be conducted more efficiently by transmitting the supplemental channels from a signal base stations 32. If, however, the behavior detected indicates a fading channel exists to subscriber unit 30b, the supplemental channels are transmitted from both base stations 32 involved in the soft handoff. In both cases base stations 32a and 32b transmit the fundamental channel. In many instances, a fading channel corresponds to a moving subscriber unit 30b and a non-fading channel corresponds to a stationary subscriber unit 30b. Also, in other embodiments of the invention described herein, information other than that contained the PSMM's is used to determined the channel condition.

Once the channel condition has been determined, the selector resource notifies subscriber unit 30b which base stations 32 will be transmitting the supplemental channels using the Extended Handoff Direction Message transmitted to subscriber unit 30b via the fundamental channel. In the preferred embodiment of the invention, the base station 32 selected to transmit the supplemental channels is the one with the strongest pilot reported in the Pilot Strength Measurement Message.

FIG. 3 illustrates the operation of the cellular telephone system during soft handoff when configured in accordance with one embodiment of the invention. The operation begins at step 100 and at step 102 the channel condition experienced by the subscriber unit 30b is monitored. At step 104, it

is determined if a fading channel condition exists, and if so the supplemental channels are transmitted from both base stations involved in the soft handoff at step **106**. Step **102** is then performed again.

If a fading channel does not exist the supplemental channels are transmitted from only one base station involved in the soft handoff at step **110**. In the preferred embodiment of the invention, the base station **32** selected to transmit on both the fundamental and supplemental channels is the base station for which the associated pilot channel is received with the greatest strength. After the system is configured at step **110**, step **102** is performed again.

By monitoring the channel condition the selector resource can determine the more optimal method for conducting the high data rate soft handoff and therefore increase overall system capacity. In general, a stationary subscriber unit **30b** is more likely to experience an additive white Gaussian noise (AWGN) channel or static multipath conditions while a moving subscriber unit **30b** is more likely to experience a fading channel. AWGN or static multipath channels do not benefit from spatial diversity of signal source while signals transmitted through fading channel can benefit from spatial diversity of signal source.

Thus, by transmitting the supplemental channels from only one base station **32** in an AWGN or static multipath channel condition, the amount of additional interference generated by the soft handoff is reduced without impacting performance. The performance is not impacted because in an AWGN channel condition, the benefit derived from transmitting the same forward link channel twice is reduced. Thus, transmitting the supplemental channels from only one base station is more optimal under these conditions.

Furthermore, by transmitting the fundamental channel from both base stations **32**, the reliability of the signaling messages transmitted during soft handoff is maintained. If voice is transmitted on the fundamental channel, then high reliability is maintained for the voice as well. Keeping signaling message transmission reliable maintains the robustness of the soft handoff, as changes in the channel condition can be compensated for by reconfiguration via exchange of more signaling messages between the selector resource and subscriber unit **30b**.

The channel condition experience by subscriber unit **30b** will generally be based on a variety of environmental factors including the load on each base station **32** and the geographic environment of the surroundings. Additionally, the channel condition also depends on the rate at which

subscriber unit 30b is moving. Thus, if the subscriber unit is stationary, the selector will typically establish the soft handoff using one base station 32 for the supplemental channels. Therefore, such control by the selector is particularly useful when subscriber unit 30b is not moving.

Various implementations of the invention use different criteria to determine the channel condition based on the set of PSMM's received from subscriber unit 30b. In one embodiment of the invention, the selector monitors for changes in the source of the strongest pilot channel as measured for the two or more base stations 32 involved in the soft handoff. If the source of the strongest pilot channel changes in excess of a given rate, the selector resource configures the set of base stations 32 to transmit the supplemental channels.

The selector resource can also monitor the PSMM's for changes in the sum of the pilot channel strengths reported. If the sum of the pilot channel strengths reported changed by more than a predetermined amount, or faster than a predetermined rate, the selector resource responds by configuring the other base station (or base stations) to transmit the supplemental channels as well.

The selector resource can also monitor the PSMM's for changes in the pilot identities reported. If the identities of the pilots reported changes the selector resource responds by configuring the other base station 32 (or base stations) to transmit the supplemental channels as well.

The selector resource can also monitor the PSMM's for changes in the pilot PN phases reported. If the pilot PN phases reported change by more than a predetermined amount, or faster than a predetermined rate, the selector resource responds by configuring the other base station 32 (or base stations) to transmit the supplemental channels as well. The pilot PN phase is the state of the pseudorandom noise (PN) code used to generate the pilot channel, and changes in the pilot PN phase indicate changes in the distance between subscriber unit 30b and the corresponding base stations 32. The above mentioned parameters can also be monitored by the subscriber unit 30b, and when one of the parameters changes more than an associated threshold, subscriber unit 30b responds by reporting the change using signaling. This allows the selector resource to respond to changing condition while minimizing the number of signaling messages, as subscriber unit 30b will not transmit any such signaling if the parameters do not change by a sufficient amount.

In another variation of the invention, the selector resource monitors the EIB bits received via the reverse link. Thus, the channel condition is

determined using information not contained in PSMM's. As noted above, EIB bits with a value of logic one indicate errors at the subscriber unit **30b** in reception of the forward link frames. Therefore, receipt of a significant number of EIB bits with values equal to one indicates a channel condition worse than expected. If the soft handoff is being conducted using a single transmission of the supplemental channel forward link signal, and the frame error rate exceeds a predetermined threshold, the selector responds by configuring the other base station 32 (or base stations) to transmit the supplemental channels as well.

In still another embodiment of the invention, the selector resource monitors the source of the frames selected during frame selection. As described above, call selection is the repeated selection of reverse link frame every 20 ms from base stations **32a** and **32b** based on the quality of the frame. If the source (i.e. base station) of the selected frames changes at a rate above a predetermined threshold, this indicates a fading channel condition which implies subscriber unit **30b** is non-stationary. The selector resource responds to such rapid changes in the source of the selected frame by configuring both base stations 32 involved in the soft handoff to transmit the supplemental channels.

In the case of softer handoff, which is a handoff between two sectors of the same base station, frame selection is not performed since the signals are combined at the base station 32. For softer handoff, the base station can report changes in the relative strengths of the various mutipath instances, or "paths" of the reverse link signal being processed to the selector resource. The selector resource then determines whether the source of the strongest path is changing, and if so configure the sectors in accordance with a fading channel. That is, the selector resource configures both sectors to transmit the fundamental and supplemental channels.

In another embodiment of the invention, subscriber unit **30b** generates PSMM's when the strength of the pilot channel from a base station 32 transmitting only the fundamental channel exceeds a threshold T_COMP_SUP less than the strength of the weakest pilot from a base station 32 transmitting the supplemental channels. The selector resource responds by instructing the base station 32 transmitting only the fundamental channel to begin transmitting the supplementary channels.

Other factors may be used to determine which base station 12 should transmit the supplemental channels. In particular, each base station 12 can monitor the amount of transmit power available for the supplemental channels, and if it exceeds a predetermined threshold, indicate such to the

selector resource. The selector resource responds by designating a different base station 12 to transmit the supplemental channels. The base station 12 chosen is the one being received at the next highest strength. The predetermined threshold can be based on a variety of factors including the maximum transmit power capability of the base station 12.

As the soft handoff is conducted, the selector constantly evaluates the channel condition, and if the channel condition changes the soft handoff is reconfigured. For example, if a fading channel becomes a non-fading channel, the selector resource configures one base station 12 to stop transmitting the supplemental channel.

The base station 12 may also examine whether the strength of the reported pilot channel is within a second threshold, T_ADD_SUP, of the strength of the weakest pilot channel already transmitting the supplementary channels before deciding whether to transmit the supplementary channels from the second base station 12.

The subscriber unit 30b may also have a T_DROP_SUP which behaves very similar to the T_DROP threshold in IS-95 for use with the fundamental channel. In this case, if the pilot corresponding to a supplemental channel falls below T_DROP_SUP relative to the strongest pilot having a supplemental channel, the subscriber unit reports the pilot. In this case, the selector resource may stop transmitting reported base station 12 from transmitting the supplemental channels.

In another exemplary embodiment of the invention, the impact of the transmission of high rate data on the capacity of the system is further reduced by transmitting the fundamental channel at a different power than the supplemental channels during either soft handoff or single interface communication, or both. In one embodiment of the invention, the supplemental channels are transmitted at a lower power level than the fundamental channel. Since the supplemental channels carry only data which is protected by the radio link protocol (set forth in IS-99 and IS-657, and described in greater detail below), rather than signaling, the modest increase in the frame error rate caused by this lower transmit power will not result in damage to the data integrity.

Additionally, if an error in the transmission of data over the supplemental channel is experienced, the affected data frame can be retransmitted at some later time. Indeed, the data transfer protocol standard IS-99and IS-657, designed for use with the IS-95 standard, provides a radio link protocol (RLP) whereby improperly received frames are retransmitted. Retransmission is more suitable for data transmissions, when compared to

voice, because data transmissions are generally more tolerant of delay than voice transmissions. For voice transmissions a delay of more than 100 ms (one tenth of a second) are noticeable during a conversation.

Retransmissions of improperly received frames substantially reduces the effective error rate of the data channel (also called the packet error rate) relative to the actual frame error rate (FER). In many instances, the benefit of RLP retransmission is sufficiently large that the effective error rate of the supplemental channel is less than the effective error rate of the fundamental channel without RLP (the frame error rate). Thus, by reducing the transmit power of the supplemental channels and retransmitting bad frames, the total transmit power of the high speed forward link is reduced without impacting performance.

It should be noted that in some embodiments of the invention the combined transmit power of the fundamental and supplemental channels is also adjusted in unison in response to other power control commands. During these combined adjustments, the relative transmit power of the supplemental and fundamental channels remains the same.

In an alternative embodiment of the present invention, the supplemental channel is transmitted at a power level that is at a predetermined offset relative the power level at which the fundamental channel is transmitted. In this second embodiment of the invention, the offset is adjusted upon detection of a change in channel condition. The change in channel condition can be detected by any of the methods described above.

The transmit power of the fundamental and supplemental channels is preferably controlled by the selector resource, which transmits power adjustment signaling to the base stations **32** transmitting the fundamental and supplemental channels. Each base station responds by adjusting the transmit power of the supplemental channels and the fundamental channel.

To allow the selector to determine the proper adjustment, the frame error information of the fundamental channel and the supplemental channels are transmitted by subscriber unit **30b** via reverse link signaling messages or the EIB bits. For example, a Power Strength Measurement Report (PSMR) message could be defined which provides the error rate of each supplemental channel. The error information can also be conveyed using RLP negative-acknowledgment (NAK) transmitted by subscriber unit **30b** on the reverse link in accordance with the use of IS-99 or IS-657. A NAK indicates that a data frame was not received properly, allowing the selector

resource to determine which frames were not received correctly, and thus the frame error rate as well as the actual error rate after retransmission.

In an alternative embodiment of the invention the error rate is determined from power control commands or other error rate indication information transmitted in a power control subchannel included in the reverse link signal. Examples of reverse link signals that include power control subchannels are provided in copending US Patent Applications Serial No. 08/766,372 entitled "Phase Shift Encoded Subchannel" and Serial No. 08/654,433 entitled "High Data Rate CDMA Wireless Communication System" both assigned to the assignee of the present invention and incorporated herein by reference. Additionally, a reverse link subchannel is also described in US Patent No. 5,383,219 entitled "Fast Forward Link Power Control in a Code Division Multiple Access System" assigned to the assignee of the present invention and incorporated herein by reference.

The error rate could also be determined using the error indicator bits included in Rate Set 2 frames.

In another embodiment of the invention the supplemental channels can be transmitted at a higher tranamit power than the fundamental channel. This would be the case when the data being transmitted via the supplemental channel requires a very low error rate, or was delay sensitive and could not be retransmitted, or both. In an example of such a communication, the subscriber unit **30b** notifies the selector resource via signaling that delay intolerant data is being transmitted, and the selector responds by increasing the transmit power of the supplemental channel via additional signaling transmitted to base stations **32**. Transmitting the supplemental channels at a higher power further can increase the capacity of the cellular telephone system because it reduces the need to generate multiple transmissions of the supplemental channels from two base stations **32** during soft handoff.

Thus, a novel and improved method and apparatus for controlling the transmit power necessary for the proper operation of a high rate link is described. The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. For example, combinations of any of the methods for detecting the channel condition described above may be used. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein

but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

I (WE) CLAIM:

CLAIMS

1. A method of controlling handoff in a communication system in which data is transmitted to a remote station by providing a first subset of said data on a fundamental channel and a second subset of said data on at least one supplemental channel, the method comprising:

receiving a pilot strength measurement message from said subscriber unit;

selecting a plurality of base stations for providing transmissions to said subscriber unit on said fundamental channel based on said pilot strength measurement message; and

independently selecting at least one of said plurality of base stations for providing transmissions to said subscriber unit on said at least one supplemental channel.

2. The method as claimed in Claim 1 further comprising transmitting to said subscriber unit an extended handoff direction message indicating the identities of said plurality of base stations for communication of said first subset of data and indicating the identity of said at least one of said plurality of base stations for communication of said second subset of data.

3. The method as claimed in Claim 1or 2 wherein said step of independently selecting at least one of said plurality of base stations comprises the steps of:

determining whether said subscriber unit is stationary; and

selecting a base station corresponding to the strongest pilot signal in said pilot strength measurement message as said at least one of said plurality of base stations when said subscriber unit is determined to be stationary.

4. The method as claimed in Claim 1, 2 or3 wherein said step of independently selecting at least one of said plurality of base stations comprises the steps of:

comparing the strengths of pilot signals in said pilot strength measurement message with the strengths of pilot signals in a prior pilot strength measurement message to determine an amount of change in said pilot strengths; and

selecting a plurality of base stations to communicate with said remote station when said amount of change in said pilot strengths exceeds a predetermined threshold.

5. The method as claimed in Claim 4 wherein said amount of change in said pilot strengths is the rate of change in said pilot strengths.

6. The method as claimed in any preceding Claim wherein said step of independently selecting at least one of said plurality of base stations comprises:

summing the strengths of pilots in said pilot strength measurement message;

comparing said sum of strengths of pilot signals in said pilot strength measurement message with a sum of strengths of pilot signals in a prior pilot strength measurement message to determine a change in said sum of pilot strengths; and

selecting a plurality of base stations to communicate with said remote station when said sum of pilot strengths exceeds a predetermined threshold.

7. The method as claimed in any preceding Claim further comprising:

determining at said subscriber unit the presence of frame errors in said data;

generating an error indicator message in accordance with said determination of the presence of frame errors in said data; and

transmitting said error indicator message;

wherein said step of selecting at least one of said plurality of base stations is performed in accordance with said error indicator message.

8. The method as claimed in Claim 7 wherein said selecting at least one of said plurality of base stations in accordance with said error indicator message comprises selecting a plurality of base stations when error rate exceeds threshold.

9. An apparatus for controlling hand-off of a subscriber unit between a plurality of base stations, the apparatus comprising:

means for controlling transmission of data in a fundamental channel and in supplemental channels; and

means for selecting plural base stations for transmission of data in the fundamental channel and for selecting one or more of the plural base stations for transmission of data in the supplemental channel.

10. An apparatus as claimed in claim 9, further comprising:

means for evaluating parameters relating to fundamental and supplemental channel signals received by a subscriber unit to determine the quality thereof; and

means for controlling the transmission of the supplemental channel signals during hand-off from a single base station if the quality indicates a non-fading signal, and from plural base stations if the quality indicates a fading signal.

11. A method of controlling hand-off of a subscriber unit between a plurality of base stations, the method comprising:

controlling transmission of data in a fundamental channel and in supplemental channels;

selecting plural base stations for transmission of data in the fundamental channel; and

selecting one or more of the plural base stations for transmission of data in the supplemental channel.

12. A method as claimed in claim 11, further comprising:

evaluating parameters relating to fundamental and supplemental channel signals received by a subscriber unit to determine the quality thereof; and

controlling the transmission of the supplemental channel signals during hand-off from a single base station if the quality indicates a non-fading signal, and from plural base stations if the quality indicates a fading signal.

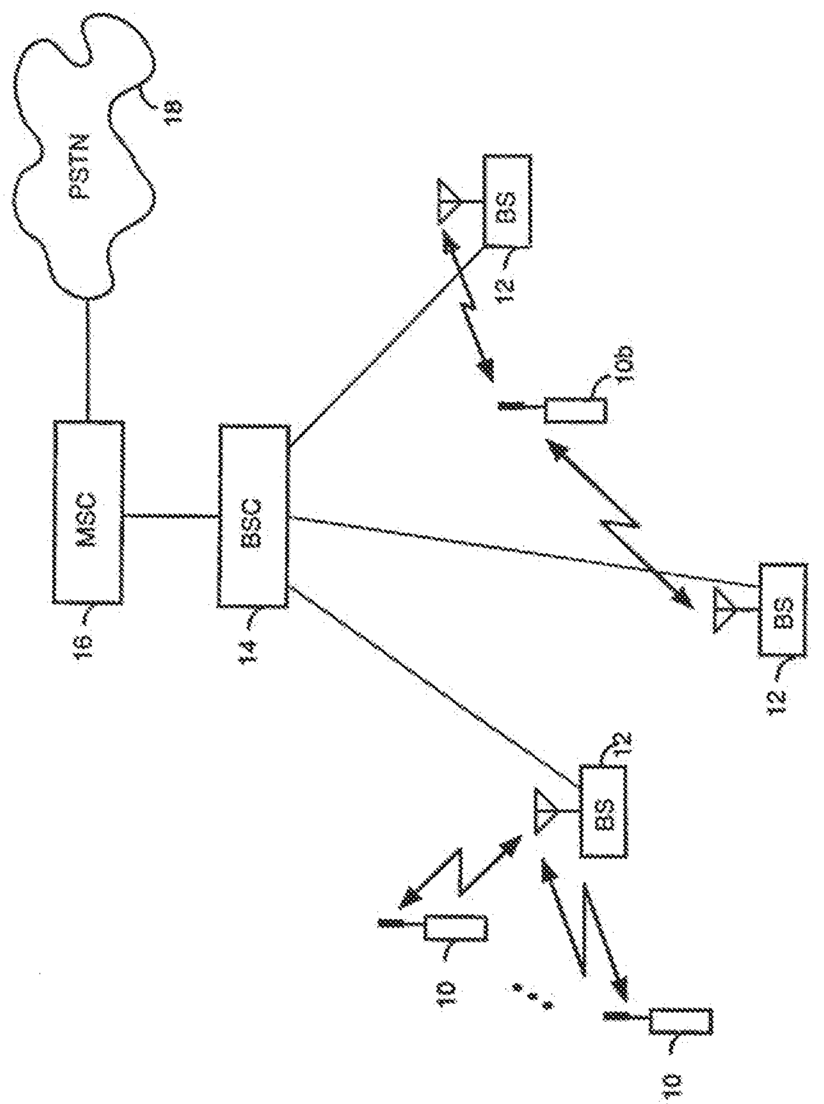


FIG. 1

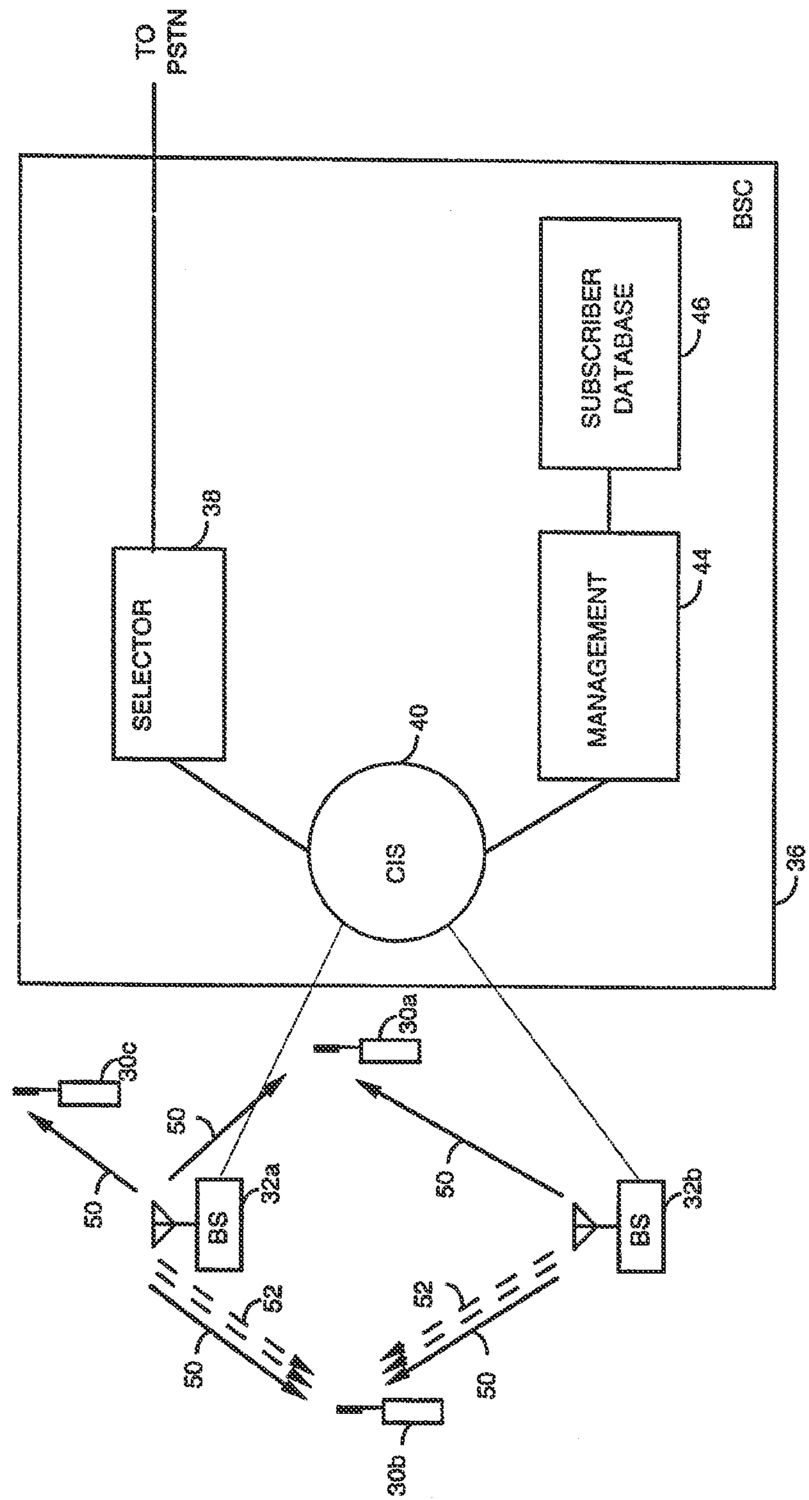

TO PSTN
BSC
SELECTOR
38
SUBSCRIBER DATABASE
46
MANAGEMENT
44
CIS
40
36
30a
30b
30c
BS
32a
BS
32b
50
52

FIG. 2

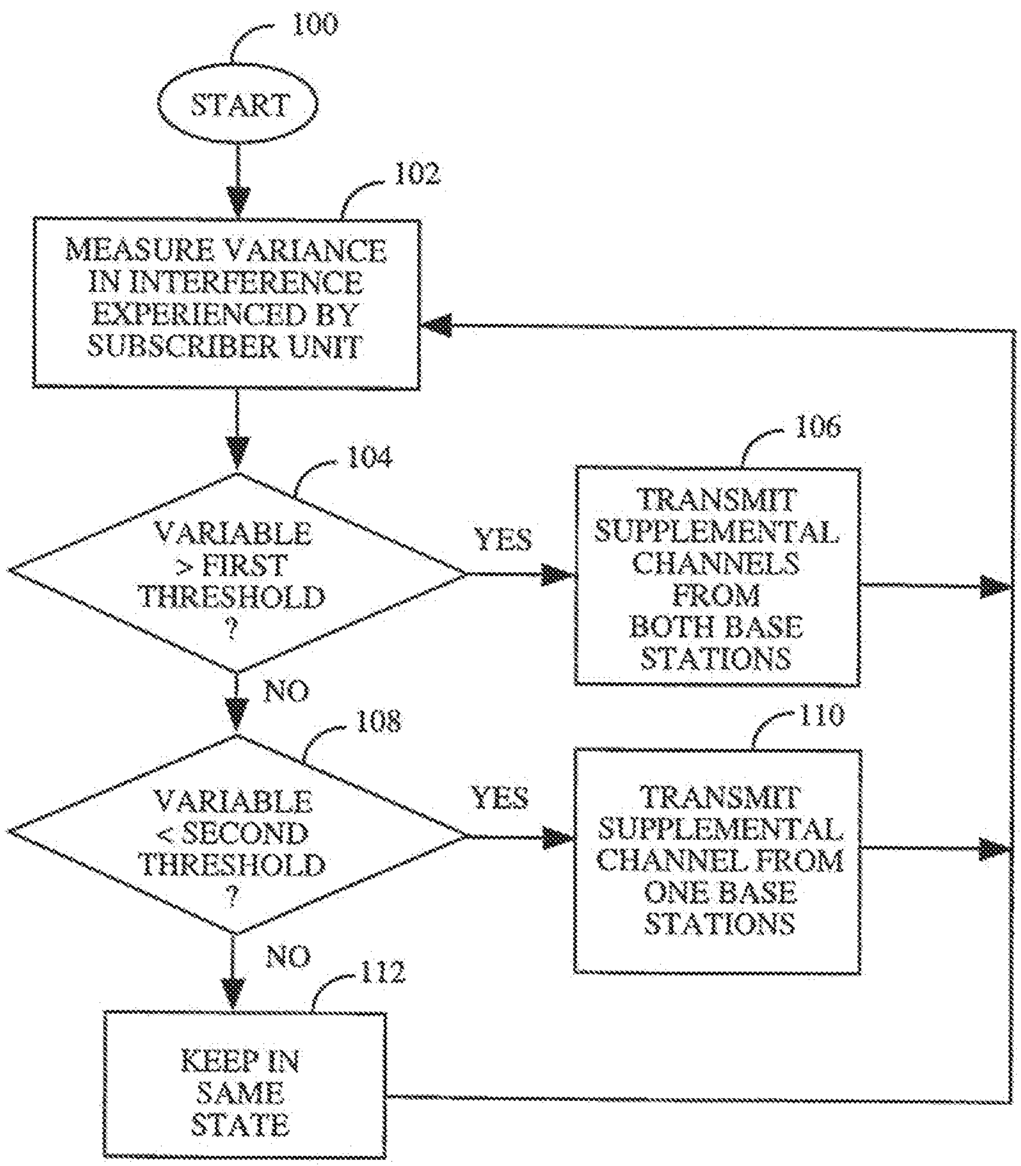

100
START
102
MEASURE VARIANCE IN INTERFERENCE EXPERIENCED BY SUBSCRIBER UNIT
104
VARIABLE > FIRST THRESHOLD ?
YES
106
TRANSMIT SUPPLEMENTAL CHANNELS FROM BOTH BASE STATIONS
NO
108
VARIABLE < SECOND THRESHOLD ?
YES
110
TRANSMIT SUPPLEMENTAL CHANNEL FROM ONE BASE STATIONS
NO
112
KEEP IN SAME STATE

FIG. 3

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04B 7/26	A1	(11) International Publication Number: WO 99/12282 (43) International Publication Date: 11 March 1999 (11.03.99)

(21) International Application Number: PCT/SE98/01539

(22) International Filing Date: 28 August 1998 (28.08.98)

(30) Priority Data:
08/924,709 29 August 1997 (29.08.97) US

(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S–126 25 Stockholm (SE).

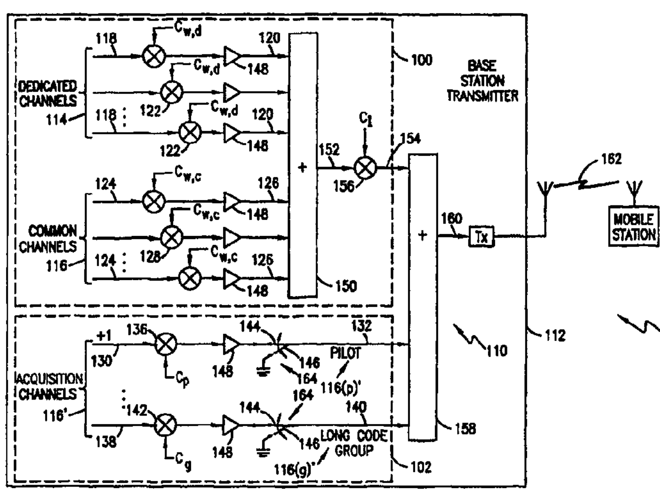
(72) Inventors: JAMAL, Karim; Ryttmästarvägen 84, S–167 70 Stockholm (SE). ESMAILZADEH, Riaz; 1–1–25–111 Ooka, Minami–ku, Yokohama 232–0061 (JP). DAHLMAN, Erik; Tackjärnsvägen 12, S–168 68 Bromma (SE).

(74) Agent: ERICSSON RADIO SYSTEMS AB; Common Patent Dept., S–164 80 Stockholm (SE).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: DOWNLINK CHANNEL HANDLING WITHIN A SPREAD SPECTRUM COMMUNICATIONS SYSTEM



(57) Abstract

With respect to a direct sequence, code division multiple access spread spectrum transmitter, symbol information relating to dedicated/common channels (114, 116) (such as the traffic or control channels) is spread to generate a plurality of corresponding dedicated/common channel intermediate signals. These intermediate signals are then summed (150) to generate an output signal (152) that is scrambled by a selected scrambling code. Symbol information relating to acquisition–related channels (such as synchronization information or the pilot or long code group code channels) (116) is also spread to generate a plurality of corresponding acquisition–related intermediate signals. These acquisition–related intermediate signals are then selectively (164) added (158) to the scrambled output signal producing a downlink signal (160) for multi–channel transmission over a communications medium (162) sharing one transmission communications frequency.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

DOWNLINK CHANNEL HANDLING WITHIN A SPREAD SPECTRUM COMMUNICATIONS SYSTEM

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to spread spectrum communications systems and, in particular, to the handling of the various channels transmitted on the downlink from a base station operating in a spread spectrum communications system.

Description of Related Art

The cellular telephone industry has made phenomenal strides in commercial operations throughout the world. Growth in major metropolitan areas has far exceeded expectations and is outstripping system capacity. If this trend continues, the effects of rapid growth will soon reach even the smallest markets. The predominant problem with respect to continued growth is that the customer base is expanding while the amount of electromagnetic spectrum allocated to cellular service providers for use in carrying radio frequency communications remains limited. Innovative solutions are required to meet these increasing capacity needs in the limited available spectrum as well as to maintain high quality service and avoid rising prices.

Currently, channel access is primarily achieved using Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) methods. In frequency division multiple access systems, a physical communication channel comprises a single radio frequency band into which the transmission power of a signal is concentrated. In time division multiple access systems, a physical communications channel comprises a time slot in a periodic train of time intervals over the same radio frequency. Although satisfactory performance is being obtained from FDMA and TDMA communications systems, channel congestion due to increasing customer demand commonly occurs. Accordingly, alternate channel access methods are now being proposed, considered and implemented.

Spread spectrum comprises a communications technique that is finding commercial application as a new channel access method in wireless communications. Spread spectrum systems have been around since the days of World War II. Early

applications were predominantly military oriented (relating to smart jamming and radar). However, there is an increasing interest today in using spread spectrum systems in communications applications, including digital cellular radio, land mobile radio, and indoor/outdoor personal communication networks.

Spread spectrum operates quite differently from conventional TDMA and FDMA communications systems. In a direct sequence code division multiple access (DS-CDMA) spread spectrum transmitter, for example, a digital symbol stream for a given dedicated or common channel at a basic symbol rate is spread to a chip rate. This spreading operation involves applying a channel unique spreading code (sometimes referred to as a signature sequence) to the symbol stream that increases its rate (bandwidth) while adding redundancy. Typically, the digital symbol stream is multiplied by the unique digital code during spreading. The intermediate signal comprising the resulting data sequences (chips) is then added to other similarly processed (i.e., spread) intermediate signals relating to other channels. A base station unique scrambling code (often referred to as the "long code" since it is in most cases longer than the spreading code) is then applied to the summed intermediate signals to generate an output signal for multi-channel transmission over a communications medium. The dedicated/common channel related intermediate signals advantageously then share one transmission communications frequency, with the multiple signals appearing to be located on top of each other in both the frequency domain and the time domain. Because the applied spreading codes are channel unique, however, each intermediate signal transmitted over the shared communications frequency is similarly unique, and through the application of proper processing techniques at the receiver may be distinguished from others.

In the DS-CDMA spread spectrum mobile station (receiver), the received signals are recovered by applying (i.e., multiplying, or matching) the appropriate scrambling and spreading codes to despread, or remove the coding from the desired transmitted signal and return to the basic symbol rate. Where the spreading code is applied to other transmitted and received intermediate signals, however, only noise is produced. The despreading operation thus effectively comprises a correlation process comparing the received signal with the appropriate digital code to recover the desired information from the channel.

In one known prior art transmitter implementation, the spreading process used by the base station for the common channel type broadcast control channel (BCCH) is a little different than that implemented with respect to the other dedicated/common channels. The pilot codes for the base station, as well as the long (scrambling) code group codes that provide information indicative of which long code is being used by the base station, are embedded within the broadcast control channel information. These pilot codes and long code group codes are transmitted periodically. The time intervals during which these codes are sent last for one symbol, and are referred to as "long code masked symbols". At each instance of long code masked symbol transmission, the pilot codes and the long code group codes are sent instead of sending the broadcast control channel. This is accomplished by turning off the broadcast control channel information stream, and instead transmitting the pilot code modulated by a known symbol (such as "+1"). At the same time, the long code group code is similarly transmitted, again modulated by a known symbol (such as "+1"). As these codes are transmitted simultaneously, it is preferable that the pilot codes and the long code group codes be orthogonal to each other. Furthermore, for only these code transmissions, the base station unique digital code (the "long code") is removed. This is accomplished, for example, by multiplying the pilot codes and the long code group codes by the complex conjugate of the long code.

From an implementation point of view, the scheme described above for implementing the transmission of the long code masked symbols requires complicated and specific code channel signal processing (both on the hardware side and software side) for the broadcast control channel that differs from that required for the other dedicated/common channels. It would be more economical and efficient to have a unified processing resource (hardware and/or software) for all channels on the downlink. It is also recognized that during the transmission of the long code masked symbols no broadcast control channel symbols are sent. This adversely affects the bit rate of the broadcast control channel. Preferably, the unified processing resource should improve the information transmission rate of the broadcast control channel.

SUMMARY OF THE INVENTION

Dedicated and common channel symbols for a direct sequence, code division multiple access spread spectrum transmitter are spread through application of appropriate spreading codes to generate a plurality of corresponding dedicated/common channel intermediate signals. These intermediate signals are then summed to generate an output signal that is scrambled by a selected scrambling code. The dedicated and common channels comprise such channels as traffic channels and control channels. The symbols for channels relating to acquisition-related activities, comprising, for example, synchronization and/or reception of the pilot channel and long code group channel, are also spread through application of an appropriate spreading code to generate a plurality of corresponding acquisition-related intermediate signals. The acquisition-related intermediate signals are then selectively added to the scrambled output signal relating to the dedicated/common channel intermediate signals producing a transmitter downlink signal for multi-channel transmission over a communications medium. The intermediate signals for the dedicated/common channels and the acquisition-related channels advantageously then share one transmission communications frequency, with the multiple intermediate signals for these channels appearing to be located on top of each other in both the frequency domain and the time domain.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be obtained by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

FIGURES 1A and 1B are block diagrams of a prior art direct sequence code division multiple access (DS-CDMA) spread spectrum transmitter such as that which would be implemented in a base station of a cellular communications system; and

FIGURE 2 is a block diagram of a present invention direct sequence code division multiple access spread spectrum transmitter such as that which would be implemented in a base station of a cellular communications system.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to FIGURE 1A wherein there is shown a block diagram of a prior art direct sequence code division multiple access (DS-CDMA) spread spectrum transmitter 10 such as that which would be implemented in a base station 12 of a cellular communications system 13. The transmitter 10 transmits a number of channels on the downlink. These channels include both dedicated channels 14 (including both traffic and control channels) and common channels 16 (also including both traffic and control channels). For each of the dedicated channels 14, a digital symbol stream at a basic symbol rate is received on line 18. This received digital symbol stream is then spread to a transmit chip rate for output as dedicated channel intermediate signal on line 20. This spreading operation involves applying a channel unique spreading code $C_{w,d}$ (often referred to as the "signature" sequence) to the received digital symbol stream that increases its rate. A Walsh type code (w) may, for example, be used for the unique spreading code of the dedicated (d) channel. The application of the channel unique spreading code is typically made through the use of a spreader 22 implementing, for example, a multiplication or modulo-two addition.

A similar process is implemented for each of the common channels 16 (except for the common broadcast control channel (BCCH) 16' as will be described). A digital symbol stream at a basic symbol rate for the common channel is received on line 24. This received digital symbol stream is then spread to a transmit chip rate for output as common channel intermediate signal on line 26. This spreading operation involves applying a channel unique spreading code $C_{w,c}$ to the received digital symbol stream that increases its rate. A Walsh type code (w) may, for example, again be used for the unique spreading code of the common (c) channel. The application of the channel unique spreading code is typically made through the use of a spreader 28.

With respect to the broadcast control channel 16', a BCCH digital symbol stream at a basic symbol rate, or a known symbol (such as "+1"), is received on line 30. This received digital symbol stream (or known symbol) is then spread to a transmit chip rate for output as BCCH intermediate signal on line 32. This spreading operation involves applying either: (1) a channel unique spreading code $C_{w,b}$ to the received digital symbol stream; or, (2) a pilot code C_p to the known symbol. A Walsh

type code (w) may, for example, again be used for the unique digital code of the transmission (b) channel, and an orthogonal gold code may be used for the pilot channel. The application of either code is typically made through the use of a spreader 34. The selection between the BCCH digital symbol stream or known symbol for input, as well as the selection between the codes for application by spreader 34, is made by hardware and/or software switch 36. Thus, it is seen that the processing of the broadcast control channel 16' is handled differently from the other common channels 16 due to the fact that the pilot codes for the base station used for receiver acquisition operations are selectively embedded by the action of switch 36 within the broadcast control channel information.

Further, with respect to the broadcast control channel 16', a known symbol (such as "+1"), is received on line 38. This known symbol is then spread to a transmit chip rate for output as a long code group intermediate signal on line 40. This spreading operation involves applying a long code group code C_g to the known symbol. An orthogonal gold code may, for example, be used for the long code group code. The application of the long code group code is typically made through the use of a spreader 42. Output of the long code group intermediate signal is controlled by switch 36 in conjunction with the selection between the BCCH digital symbol stream or known symbol for input on line 30, as well as the selection between the codes for application by spreader 34 in generating the BCCH intermediate signal. Thus, it is seen that the processing of the broadcast control channel 16' is further handled differently from the other common channels 16 due to the fact that the long code group codes used for receiver acquisition operations by identifying, to some degree, the long code for the base station, are selectively embedded by the action of switch 36 within the broadcast control channel information.

In accordance with this selection embedding operation performed by switch 36, when the switch is in a first physical/logical position (as illustrated by solid line arrow 44), the BCCH digital symbol stream is selected for input on line 30, the BCCH intermediate signal carries broadcast control channel information, and no long code group intermediate signal is generated. Conversely, when the switch is in a second physical/logical position (as illustrated by broken line arrow 46), the known symbol is selected for input on line 30, the BCCH intermediate signal carries the pilot channel,

and the long code group intermediate signal is generated. The pilot codes and long code group codes are simultaneously transmitted on a periodic basis. The time instants when they are sent last for a duration of one symbol. At each instance of transmission, the switch 36 selects the second position (indicated by arrow 46), and the pilot codes and the long code group codes are sent instead of sending the broadcast control channel information. As the pilot codes and long code group codes are transmitted simultaneously, it is preferable that the pilot codes and the long code group codes be orthogonal to each other.

Each of the channels 14, 16 or 16' typically includes a power adjustment device 48 that processes the generated plural intermediate signals as selected by operation of switch 36 and received on lines 20, 26, 32 and 40, to effectuate individual control over the transmission power of each channel. The power controlled intermediate signals are then added together by adder 50 to generate a combined signal on line 52. This combined signal is then scrambled by a base station unique scrambling code C_l (referred to as the "long code", and identified to some degree by the long code group C_g) to generate an output signal on line 54 for multi-channel transmission over a communications medium 58. Any suitable scrambling code may be used for the long code. The application of the long code is typically made through the use of a scrambler 56 implementing, for example, a multiplication or modulo-two addition. The dedicated/common channel related intermediate signals advantageously then share one transmission communications frequency on the communications medium 58, with the multiple signals appearing to be located on top of each other in both the frequency domain and the time domain.

With respect to the simultaneously transmitted pilot code and the long code group code, the base station unique scrambling code (the "long code") is preferably removed. This facilitates detection by the receiver of the pilot code during the searching operation without having to have prior knowledge of the long code being used to scramble the transmitted dedicated and common channel information. With detection of the pilot code, the receiver may synchronize itself with the base station in order to find downlink chip boundaries, symbol boundaries and slot boundaries. Furthermore, with detection of the long code group code, an indication is provided of the long code used for scrambling the dedicated/common channels, thus allowing the

receiver during searching operation to narrow down the number of long codes that must be searched before being able to descramble the dedicated/common channels.

The removal of the long code from the simultaneously transmitted pilot code and the long code group code is referred to in the prior art as masking. Accordingly, the simultaneously transmitted pilot code and the long code group code are collectively referred to as "long code masked symbols". To accomplish this masking, the pilot codes C_p and the long code group codes C_g are, for example, multiplied by the complex conjugate C_l^* of the long code C_l prior to being multiplied with the known symbol as input on lines 30 and 38, respectively.

An alternative implementation of the prior art direct sequence code division multiple access spread spectrum transmitter 10 of FIGURE 1A is shown in FIGURE 1B. In the transmitter 10 of FIGURE 1B, like or similar elements with respect to FIGURE 1A are identified with the same reference numerals. Operation of the transmitters 10 is substantially the same. The transmitter 10 of FIGURE 1B differs in that separated handling of the broadcast control channel and pilot channel is provided.

Reference is now made to FIGURE 2 wherein there is shown a block diagram of a present invention direct sequence code division multiple access (DS-CDMA) spread spectrum transmitter 110 such as that which would be implemented in a base station 112 of a cellular communications system 113. The transmitter 110 transmits a number of channels on the downlink, and includes a block of channel equipment 100 for information carrying channels including both dedicated channels 114 (including both traffic and control channels) and common channels 116 (also including both traffic and control channels). For each of the dedicated channels 114, a digital symbol stream at a basic symbol rate is received on line 118. This received digital symbol stream is then spread to a transmit chip rate for output as dedicated channel intermediate signal on line 120. This spreading operation involves applying an individual channel unique spreading code $C_{w,d}$ (often referred to as the "signature" sequence) to the received digital symbol stream that increases its rate. A Walsh type code (w) may, for example, be used for the unique spreading code of the dedicated (d) channel. The application of the channel unique spreading code is typically made

through the use of a spreader 122 implementing, for example, a multiplication or modulo-two addition.

A similar process is implemented for each of the common channels 116 (including the common broadcast control channel (BCCH)). A digital symbol stream at a basic symbol rate for the common channel is received on line 124. This received digital symbol stream is then spread to a transmit chip rate for output as common channel intermediate signal on line 126. This spreading operation involves applying an individual channel unique spreading code $C_{w,c}$ to the received digital symbol stream that increases its rate. A Walsh type code (w) may, for example, again be used for the unique spreading code of the common (c) channel. The application of the channel unique spreading code is typically made through the use of a spreader 128.

Each of the channels 114 or 116 may include a power adjustment device 148 that processes the generated plural dedicated and common channel intermediate signals received on lines 120 and 126 to effectuate individual control over the transmit power of each channel. The power controlled intermediate signals are then added together by adder 150 to generate a combined signal on line 152. This combined signal is then scrambled by a base station unique scrambling code C_l (referred to as the "long code") to generate an output signal on line 154 for multi-channel transmission over a communications medium. Any suitable scrambling code may be used for the long code. The application of the long code is typically made through the use of a scrambler 156 implementing, for example, a multiplication or modulo-two addition.

The transmitter 110 further includes a block of channel equipment 102 for transmission of acquisition-related channels 116' such as those for use in base station acquisition by a mobile station (like the pilot codes C_p and long code groups codes C_g) which do not use either the short Walsh type codes C_w for spreading or the long codes C_l for scrambling used by the dedicated channels 114 or common channels 116. These codes are used for receiver acquisition operations, and are collectively commonly referred to in the prior art as the "long code masked symbols" since they are transmitted with the long code C_l removed. For example, with a pilot channel 116(p)' one of these channels 116' (comprising a primary synchronization channel), a known symbol (such as "+1") is received on line 130. This received known symbol is then spread to a transmit chip rate for output as pilot channel intermediate signal on line

132. This spreading operation involves applying a pilot code C_p to the received digital symbol stream that increases its rate. An orthogonal gold code may, for example, be used for the pilot channel. The application of the pilot code is typically made through the use of a spreader 136.

Further, for example, a similar process is implemented for a long code group channel 116(g)' one of these channels 116' (comprising a secondary synchronization channel). A symbol is received on line 138. This possibly known symbol is then spread to a transmit chip rate for output as a long code group intermediate signal on line 140. This spreading operation involves applying a long code group code C_g to the known symbol, that increases its symbol rate. An orthogonal gold code may, for example, be used for the long code group code. The application of the long code group is typically made through the use of a spreader 142.

Each of the channels 116' may include a power adjustment device 148 that processes the generated plural intermediate signals received on lines 132 and 140 to effectuate individual control over the transmit power of each channel. The power controlled intermediate signals for the channels 116' are then selectively added together with the scrambled combined output signal received on line 154 by adder 158 to generate a transmitter output downlink signal on line 160 for transmission. The power control process may, if necessary, be implemented in conjunction with the power control exercised over the dedicated channels 114 and common channels 116 to maintain a substantially constant power output from the transmitter 110 as various ones of channel 116' intermediate signals are added to and deleted from the overall transmitter output signal on line 160. The dedicated/common channels 114 and 116 and acquisition- related channel 116' of the output signal advantageously then share one transmission communications frequency on the communications medium 162, with the multiple signals appearing to be located on top of each other in both the frequency domain and the time domain.

Selective addition of each channel 116' intermediate signal (such as the pilot code intermediate signal or the long code group intermediate signal) used for receiver acquisition operations to the scrambled output signal for the dedicated/common channels is controlled by a plurality of hardware and/or software switches 164. One switch 164 is provided for each individual intermediate signal, with the plurality of

switches being independently or commonly selected. In accordance with this selection operation performed by switches 164, when an individual one of the switches is in a first physical/logical position (as illustrated by solid line arrow 144), the corresponding intermediate signal is passed on to the power adjustment device 148 and adder 158. Conversely, when the switch is in a second physical/logical position (as illustrated by broken line arrow 146), no corresponding intermediate signal is passed. The channel 116' intermediate signals (such as for the pilot codes and long code group codes) are transmitted on a periodic basis. At each instance of transmission, the appropriate switch 164 selects the first position (indicated by arrow 144), and the corresponding intermediate signal of the channels 116' is added to, and transmitted with, the dedicated channels 114 and common channels 116.

With respect to both implementation and operation, the transmitter 110 of the present invention is notably more efficient and economical than the prior art transceiver 10 of FIGURE 1. First, it is noted that the signal processing (both from a hardware and a software perspective) used for the broadcast control channel (BCCH) is the same as that used for any other dedicated or common channel of the transmitter 110. Thus, no unique or specific processing techniques need be implemented to handle the special circumstances surrounding the removal of the long code and the implementation of the pilot code and long code group codes in conjunction with the broadcast control channel. Second, with the use of individually controlled switches 164 for the channels 116', the transmission of the pilot codes and long code groups codes, for example, need not necessarily coincide in time. Issues concerning the maintenance of orthogonality between the codes of the channels 116' used for receiver acquisition operations are thus obviated and the interference imposed onto the dedicated and common channels may be advantageously spread in time. Third, the present implementation increases the channel bit rate of the broadcast control channel over that provided in the prior art. Since a one symbol duration masking of the broadcast control channel is no longer required, that symbol space is made available to carry more broadcast control channel information. This could be used to increase the information rate on the broadcast control channel, or could be used to increase the amount of channel encoding provided on the broadcast control channel. Such increases further serve to compensate for any additional interference caused by

common channel 116' transmissions during a common channel 116 broadcast control channel transmission. No other additional adverse affect on interference is experienced with the transceiver 110 implementation in comparison to the implementation of FIGURES 1A and 1B.

Although embodiments of the method and apparatus of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A direct sequence, spread spectrum transmitter, comprising:

a first block of channel equipment for dedicated channels and common channels of the transmitter, comprising:

a first plurality of spreaders for spreading dedicated/common channel information to generate a plurality of corresponding dedicated/common intermediate signals;

a first summer for summing the plurality of corresponding dedicated/common intermediate signals; and

a scrambler for scrambling the summed plurality of corresponding dedicated/common intermediate signals to generate an output signal;

a second block of channel equipment for acquisition-related channels of the transmitter, comprising:

a second plurality of spreaders for spreading acquisition-related channel information to generate a plurality of corresponding acquisition-related intermediate signals; and

switch means for selectively passing the plurality of corresponding acquisition-related intermediate signals; and

a second summer for summing the selectively passed plurality of corresponding acquisition-related intermediate signals with the output signal comprising the scrambled and summed plurality of corresponding dedicated/common intermediate signals to generate a downlink transmit signal for transmission by the transmitter.

2. The transmitter as in claim 1 wherein the dedicated channels and common channels comprise spread spectrum traffic and control channels.

3. The transmitter as in claim 1 wherein the acquisition-related channels comprise at least one channel with a known modulation.

4. The transmitter as in claim 1 further comprising:

a power adjustment device for making a power level selection on each intermediate signal.

5. The transmitter as in claim 4 wherein the power adjustment device further coordinates power level selection on at least one of intermediate signals to account for the selective passing of the plurality of corresponding acquisition-related intermediate signals to be summed with the output signal.

6. The transmitter as in claim 1 wherein the first plurality of spreaders apply codes from a first orthogonal code set in spreading the dedicated/common channel information.

7. The transmitter as in claim 6 wherein the second plurality of spreaders apply codes not belonging to the first orthogonal code set in spreading the acquisition-related channel information.

8. The transmitter as in claim 1 wherein the scrambler applies a long code, whose identity is indicated by the spread acquisition-related channel information, in scrambling the summed plurality of corresponding dedicated/common intermediate signals.

9. The transmitter as in claim 8 wherein the acquisition-related channel comprises a long code group code channel, the long code group code providing an indication of the selected long code used by the second plurality of spreaders in scrambling the summed plurality of corresponding dedicated/common intermediate signals.

10. A method for separated processing of direct sequence spread spectrum channel information, comprising the steps of:

for dedicated/common channel information:

spreading the dedicated/common channel information to generate dedicated/common intermediate signals;

summing the generated dedicated/common intermediate signals together; and

scrambling the summed dedicated/common intermediate signals;

for acquisition-related channel information:

spreading the acquisition-related channel information to generate a acquisition-related intermediate signal; and

selectively passing the generated acquisition-related intermediate signal; and

for both dedicated/common and acquisition-related channel information:

adding the selectively passed acquisition-related intermediate signal to the scrambled and summed dedicated/common intermediate signals to generate a downlink transmit signal for transmission.

11. The method as in claim 10 wherein the step of spreading the dedicated/common channel information comprises the step of applying codes from a first orthogonal code set to effectuate the spreading.

12. The method as in claim 11 wherein the step of spreading the acquisition-related channel information comprises the step of applying codes not belonging to the first orthogonal code set to effectuate the spreading.

13. The method as in claim 10 wherein the dedicated channels and common channels comprise a spread spectrum traffic and control channels.

14. The method as in claim 10 wherein the acquisition-related channel comprises at least one channel with a known modulation.

15. The method as in claim 10 further comprising the step of adjusting a power level of at least one intermediate signal.

16. The method as in claim 15 wherein the step of adjusting further comprises the step of coordinating adjusted power level on at least one intermediate

signal to account for the selective passing of the acquisition-related intermediate signal to be added to the scrambled and summed dedicated/common intermediate signals.

17. The method as in claim 10 wherein the step of scrambling comprises the step of applying a long code, whose identity is indicated by the spread acquisition-related channel information, in scrambling the summed dedicated/common intermediate signals.

18. The method as in claim 17 wherein the acquisition-related channel comprises a long code group code channel, the long code group code providing an indication of the long code applied in scrambling the summed dedicated/common intermediate signals.

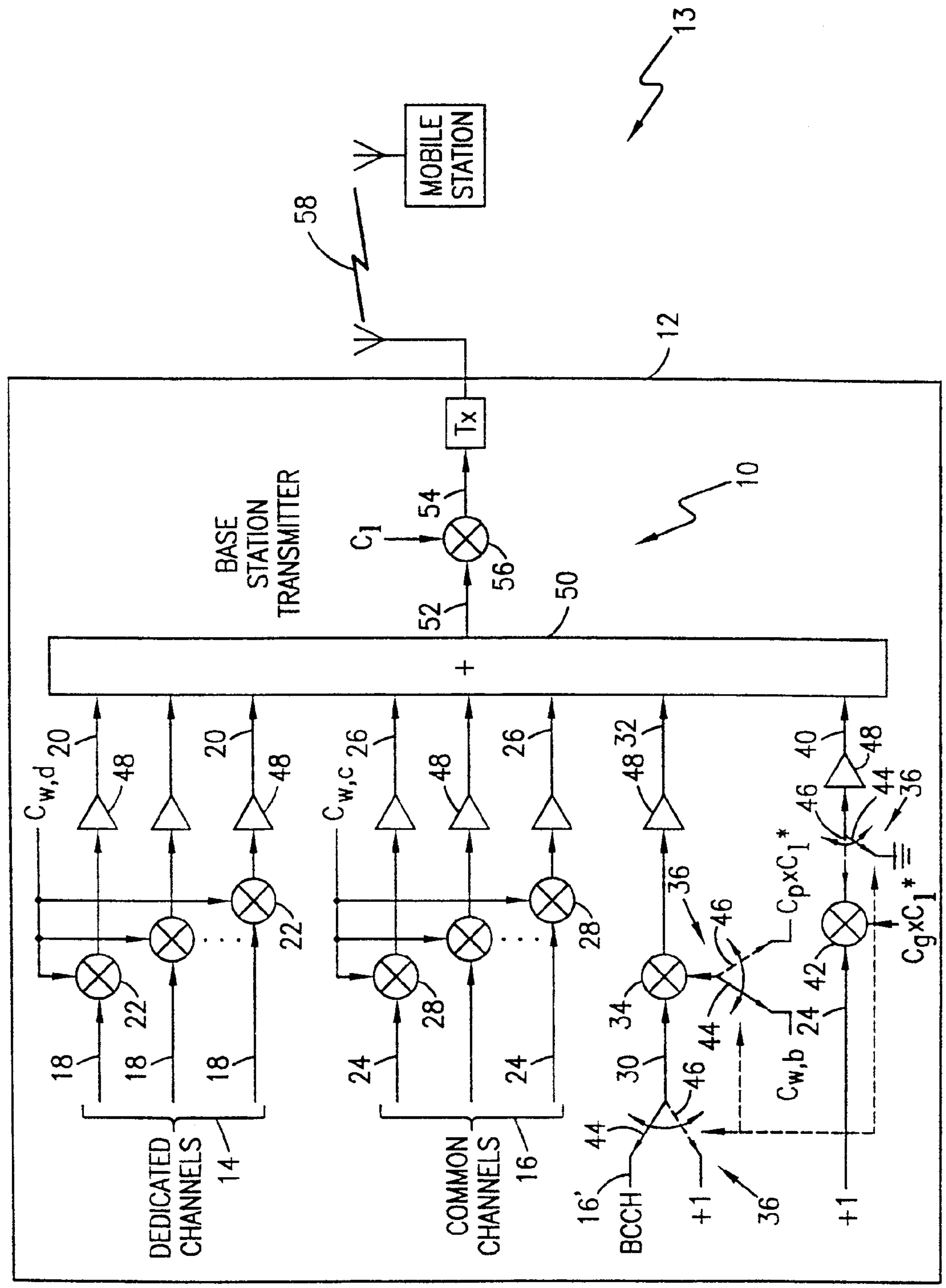


FIG. 1A (PRIOR ART)

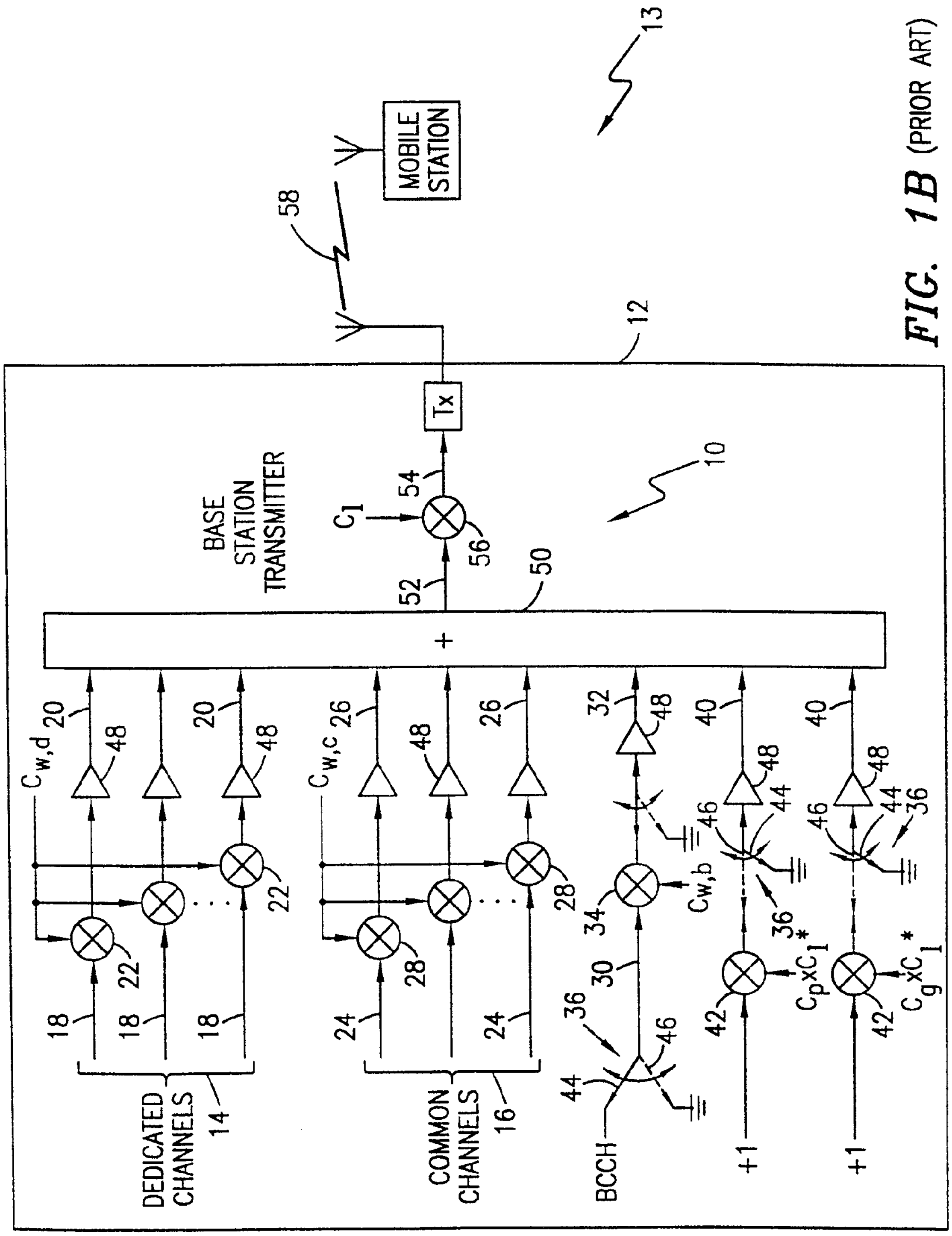


FIG. 1B (PRIOR ART)

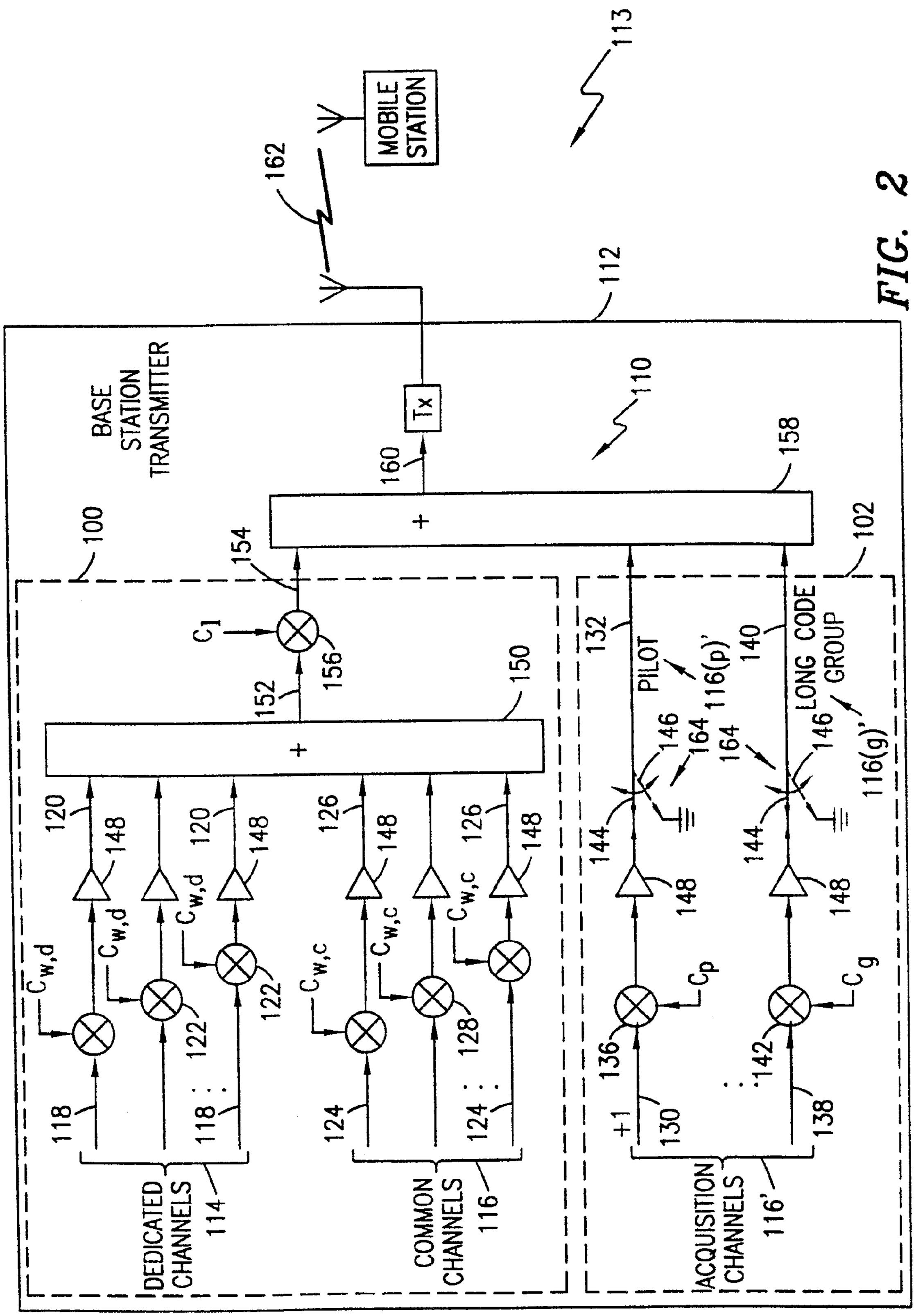

MOBILE STATION
162
113
112
BASE STATION TRANSMITTER
Tx
110
160
158
+
100
154
C_1
156
152
150
+
PILOT
132
116(p)'
LONG CODE GROUP
140
116(g)'
102
146
164
144
148
120
126
$C_{w,d}$
$C_{w,c}$
122
128
118
124
C_p
C_g
136
142
+1
130
138
DEDICATED CHANNELS
114
COMMON CHANNELS
116
ACQUISITION CHANNELS
116'

FIG. 2

INTERNATIONAL SEARCH REPORT

Interr ıal Application No
PCT/SE 98/01539

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 31428 A (LOCKHEED CORP) 28 August 1997 see page 4, line 7 - line 14 see page 8, line 4 - line 18; figure 1	1,7,10, 12
A	US 5 345 467 A (LOMP GARY R ET AL) 6 September 1994 see column 11, line 1 - column 12, line 27; figure 3	1,7,10, 12
A	EP 0 704 987 A (SONY CORP) 3 April 1996 see page 2, column 1, line 21 - line 52; figure 1	1,7,10, 12

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 1998	04/12/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bossen, M

1

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

Interr. ...ial Application No
PCT/SE 98/01539

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9731428	A	28-08-1997	US	5805584 A	08-09-1998
			AU	1838597 A	10-09-1997
US 5345467	A	06-09-1994	US	5179571 A	12-01-1993
EP 0704987	A	03-04-1996	JP	8102699 A	16-04-1996
			CN	1134633 A	30-10-1996
			US	5699380 A	16-12-1997